University of Maine

MAINE AGRICULTURAL EXPERIMENT STATION

BULLETIN No. 168.

(Papers from the Biological Laboratory No. 14.)

# DATA ON CERTAIN FACTORS INFLUENCING THE FERTILITY AND HATCHING OF EGGS



BY

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ORONO, MAINE

SEPTEMBER, 1909.

## BULLETIN No. 168.

# DATA ON CERTAIN FACTORS INFLUENCING THE FERTILITY AND HATCHING OF EGGS.*

By Raymond Pearl and Frank M. Surface.

In connection with a general investigation of the physiology of reproduction in the domestic fowl in progress at this Station especial attention has been devoted to the study of the factors which influence the hatching of eggs. As a result of the work in this direction which has been carried out during the last two years a considerable mass of data has accumulated. It is the purpose of this paper to present this material and discuss certain definite and positive results to which it leads.

It should be said at the outstart that this investigation has nothing directly to do with the problems of incubation *per se*. This will be clear if we consider briefly the questions with which the present work is concerned. The fundamental, general problem which served as the basis of the investigation may be stated in this way: What part in the determination of the relative fertility and hatching quality of eggs is played by innate, individual characteristics of the parent birds? If the eggs from a number of different females are handled in the same way and put under identical conditions of incubation it will be found that those from certain individuals will show a much higher percentage of fertile eggs and of hatched chickens than do those from other individuals. Is it not possible to determine some of the factors on which these individual differences depend? The present paper is an attempt in this direction.

Specifically we have endeavored by the use of appropriate biometric methods, to obtain reliable data on the following questions:

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*Papers from the Biological Laboratory of the Maine Agricultural Experiment Station. No. 14.

This paper forms No. IV of a series of "Studies on the Physiology of Reproduction in the Domestic Fowl," in course of publication from this Laboratory.

1. Is there any definite correlation, and if so of what degree, between the fertility of eggs on the one hand and the hatching quality of fertile eggs on the other hand? In other words, is it in general the case that if a particular hen's eggs are above the average in regard to percentage fertility, they will also be likely to be above the average in regard to percentage of fertile eggs hatched?

2. To precisely what extent does the female bird (as compared with the male) determine the fertility and hatching quality of her eggs? Bad housing conditions are known, for example, to affect adversely the percentage fertility of eggs. To what extent is this due to the bad effect of the environment on the female as contrasted with the male bird?

3. Is there any correlation, and if so of what degree, between the winter egg production preceding the breeding season and the percentage fertility of eggs? Is the bird that has produced more than the average number of eggs during the winter, likely to have her eggs during the breeding season more or less fertile than the average?

4. What relation exists between winter egg production and the hatching qualities of fertile eggs? Will the relatively high winter producer lay eggs during the breeding season likely to show a percentage of fertile eggs hatched higher or lower than the average?

5. To what extent are the fertility and hatching quality of her eggs innate, unchangeable characteristics of a bird? If a pullet produces eggs above the average for pullets in either fertility or hatching quality, will the same bird's eggs in the second year of life be above the average for yearling hens in these respects?

6. Are the characters "percentage fertility" and "percentage of fertile eggs hatched" inherited in any appreciable degree? In other words, are these fundamental characters, "bred in the bone," or are they things which are entirely influenced and determined by external, environmental influences?

It will be seen that no one of these problems is primarily a problem of incubation. It is only essential that while these problems are being studied all eggs be incubated in a uniform way. These problems can in no way be regarded as secondary in importance to those of incubation. Indeed some knowledge

regarding the points here raised is an almost absolutely necessary prerequisite to any adequate interpretation of the results of experiments on incubation.

The questions here raised are fundamental ones, intimately related to the general physiology of reproduction in the domestic fowl. The significance of a solution reaches farther than simply answering the immediate questions raised. For if it can be shown that these characters, fertility and hatching quality of eggs, are innate and unique qualities of the individual and are definitely inherited we shall then have a sure basis on which to proceed towards improving them by breeding. That there is room for improvement here is not to be doubted. The number of eggs which it takes to make a healthy chicken is a very important factor in the poultry industry, and one on which more than one otherwise promising commercial venture has been wrecked. Further, certain of the questions to be here discussed have a direct bearing on important problems of organic evolution in general. Thus the question of whether the fertility and hatching capabilities of eggs are correlated with fecundity (here measured by winter egg production) is one on which data are almost entirely wanting for any organism. Yet this is a question of prime importance in any discussion regarding the struggle for existence following the migration of a form into a new habitat. Definite data obtained under controlled experimental conditions regarding this correlation are needed.

## Material and Methods.

At the beginning of the hatching season of 1908 a system of extensive and detailed records regarding the fertility and hatching of eggs was inaugurated in connection with the poultry work of the Station. For all eggs which have been incubated since that time the following facts are known: 1. The hen that laid the egg. 2. The male bird that was in the pen with this female and which fertilized the egg, if it was fertilized. 3. The number of the pen and the number of the house in which these birds were kept. 4. The incubator in which the egg was placed. 5. The date at which the egg was laid. 6. The date at which it was put into the incubator. 7. The date or dates at which it was tested. 8. Whether the egg was (a) infertile, or (b) started to develop but the embryo died early in incuba-

tion, or (c) the embryo died late in incubation, or (d) hatched a good or a poor chick. 9. The date at which the egg hatched or failed to hatch. 10. The number of eggs which had been laid by the hen which produced this given egg before it was laid. 11. The pedigree of this hen.

Since these records have been taken for every egg put into the incubators it necessarily means that they were taken for every bird in the breeding pens during each hatching season. Both in 1908 and 1909 the female birds which were used as breeders were chiefly pullets but they also included a number of yearling and older hens which in the past had made high egg records and were on that account put into the pens as breeders. In any study of such problems as those here under discussion it is necessary that the material be homogeneous. In consequence pullets and old hens must be treated separately. The discussion which follows deals with pullets except where a specific statement to the contrary is made; namely, birds hatched either in the spring of 1907 or 1908.

Furthermore it is necessary in a discussion of these matters that all individual birds included shall have had an equal chance to produce eggs and to have them fertilized and incubated. That is to say, only birds should be included in the statistics which make a complete record for the whole hatching season—from February to June. For practical and experimental reasons it was found desirable in the 1908 work to withdraw a number of breeding birds in the course of the season and substitute others in their places. Both the withdrawn and the substituted birds are excluded from the present statistics. Leaving these various classes of birds out of account there remain 110 pullets which made complete records for the hatching season from February 8 to June 10, 1908. In the 1909 breeding season there were 87 pullets and 58 yearling hens (hatched in 1907) which made complete records for the season extending from February 1 to May 17, 1909. In both years only Barred Plymouth Rock birds are included in the statistics.

A word should be said regarding the conditions under which the breeding was done. For the breeding investigations which the Station has under way it is absolutely necessary to know the male as well as the female parent of each chicken hatched.

In order to get at such facts in a practical way it is necessary that the birds be kept in small flocks. Otherwise very few males will be represented in the pedigrees. The only place in which it was possible to make small pens to accommodate 10 to 15 birds each in the spring of 1908 was in the old, heated house No. 1. It had long been known that this house was not at all suited to breeding work. In its past history it had made a bad reputation for itself as a breeding house. The hatching eggs obtained from it had never averaged nearly so high in either fertility or in percentage of fertile eggs hatched as had eggs produced in the curtain front houses Nos. 2 and 3. Fully aware of this fact and of the low absolute averages which it would mean in the work it was nevertheless necessary, for the reason which has already been stated, to use this house in the breeding work in 1908. This fact accounts for the low averages of fertility and hatching which are exhibited in the tables for 1908 which follow. These averages are not to be taken as representative of what the Station's birds would do under more favorable conditions.

The bad effect of house No. 1 on the fertility and hatching qualities of the eggs was very clearly shown even in the 1908 work itself since there were available for comparison the records of two pens of 15 pullets each kept in house No. 2 in curtain front pens. As will be shown farther on the records for these two pens exhibit a much superior fertility and hatching quality of the eggs than do those of the pens in No. 1 house.

Before the breeding season of 1909 the curtain front house No. 2, was remodeled and fitted up particularly for use as a breeding house. Each of the seven pens into which it was originally divided was again divided into two by a semi-removable partition. This gave 14 breeding pens 10′ x 13′, all of the curtain front pattern. All of the breeding work in 1909 was carried on in these pens.

In the 1908 work 10 female and 1 male bird were put in each of the small pens of house No. 1. In 1909 15 female and 1 male bird were put in each of the breeding pens of house No. 2 just described. This difference in method, together with the fact that in one year the breeding was done in a closed, heated house, and in the other year in a curtain front house render the statistics of one year not directly comparable with those

of the other. Nowhere in this paper are the statistics of these two years lumped together. So long as the figures for the two years are not lumped together and conclusions are not drawn which depend upon joining of one of the years with the other, it is a great advantage to have the conditions so different in the two years. It affords an opportunity to determine whether relations which obtain under one set of conditions will hold under a totally different set.

The hatching in all of this work was, as in previous years, done in incubators. All incubators used were Cyphers No. 3 (360 egg) machines. The only methods used which differed at all from those previously followed in the Station's poultry work were such as were necessitated by the fact that pedigree records were kept.* The eggs from the different birds were all handled in the same way and subjected to the same conditions so that *differences* in hatching results can not be referred to the treatment which the eggs received. It is conceivable that the hatching records as a whole might be improved or made poorer by using some other methods of handling the eggs during incubation. But it is not conceivable that when all eggs are handled in the same way differences between the eggs of two individual hens in regard to hatching qualities can be explained as the result of the handling. Such differences are inherent in the eggs themselves. It is with differences of this kind that this paper has to do. Care was taken to insure that the eggs from given individual hens should be distributed at random through the different incubators, in order to guard against any possible inequality of treatment from this source.

The eggs were tested for fertility by candling in the usual way. This testing was done by Mr. Walter Anderson. His long experience in work of this sort insures the substantial accuracy of the fundamental data. In the 1908 work a check was kept on the determinations by opening eggs at intervals. It is not contended that the records of infertile eggs of that year include absolutely none that had begun development and stopped very early. Such absolute accuracy is unattainable without opening every egg. The number of errors of this kind in the records we know to be very small, however. There can be no question that they do not in any way affect the results.

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* Cf. Me. Agr. Expt. Stat. Bulletin 159.

Our certainty on this point was gained through a change of plan which was adopted in the 1909 breeding season. This year the eggs were candled and sorted as before by Mr. Anderson. Then every egg which did not hatch was opened by the writers, and the accuracy of the original candling result tested by direct examination of the contents of the egg. This method did two things. In the first place it made the 1909 records as nearly absolutely accurate as it is possible to get them, and in the second place it demonstrated to us the very high degree of accuracy of Mr. Anderson's candling.

In this discussion of the fertility and hatching of eggs it is necessary to define the terms used with some precision, since the term "fertility of eggs" in particular is used with rather widely different meanings by different writers on poultry topics. Considered from the strictly scientific standpoint there can exist no such thing as "degrees of fertility." One very commonly hears and sees the statement made that particular eggs are "strongly fertilized," or that such a cockerel, owing perhaps to lack of constitutional vigor, causes the eggs to be "weak in fertility," meaning that the embryos die in the shell after a few days incubation. From the biological standpoint an egg is either fertilized or it is not. The act of fertilization consists essentially in the union of a single spermatozoön with a single egg cell. If this union takes place the egg is fertilized. If it does not take place it is not fertilized. Reducing this consideration to a practical basis it means that the only logical process is to record as infertile only those eggs which do not start at all to develop, and to regard as fertile any egg which begins development, even though development may stop in such an egg within 24 hours after incubation begins. In taking the records at the Station eggs are usually divided into four classes; namely, (a) those which are infertile; (b) those that are fertile but in which the germs die soon (that is within two or three days) after development begins; (c) those that die in the shell at a later stage of development and (d) the eggs that hatch. In all the discussion which follows it will be understood that an infertile egg means one which does not start to develop because no spermatozoön has united with it, and that hatching means the production of a *live* chick from the egg.

## The Relation between the Fertility and Hatching Quality of Eggs.

It is obvious that fertility and hatching quality or ability of eggs are two essentially different things. A hen may have a small proportion of her eggs fertile and yet hatch a very high percentage of what of the eggs are fertile, producing therefrom healthy chickens. Or, conversely, the eggs of a particular hen may run very high in fertility but none, or very few, of the fertile eggs hatch. These facts are well known to every poultryman. Some striking illustrations of them taken from the Station's records of the 1908 hatching are shown in Table I. These illustrations are not the most extreme ones which might have been found. They are simply cases which came first to hand in looking over the records, and which show clearly that high fertility does not necessarily mean good hatches and *vice versa*.

TABLE I.

*Illustrative Cases Showing Relation Between Fertility and Hatching Quality of Eggs.*

| Band number of bird. | Total number of this bird's eggs set. | Per cent. of these eggs which were fertile. | Per cent. of fertile eggs hatched. | Number of *different* incubators in which these eggs were set. |
|---|---|---|---|---|
| 393 | 57 | 91 | 12 | 6 |
| 27 | 48 | 92 | 18 | 7 |
| 757 | 62 | 90 | 23 | 7 |
| 707 | 30 | 100 | 20 | 3 |
| 375 | 45 | 64 | 41 | 7 |
| 705 | 32 | 66 | 38 | 5 |
| 753 | 57 | 54 | 61 | 7 |
| 745 | 41 | 59 | 50 | 4 |

It will be seen that the table is divided into two parts. The upper half includes 4 pullets whose eggs ran high in fertility but hatched very poorly. The lower half of the table exhibits the records of birds showing exactly the opposite condition of affairs. The eggs of these pullets ran relatively low in fertility

but hatched very well. The last column of the table is inserted for the purpose of showing that the differences in these individual records are not to be attributed to differences in incubation. The figures in this column show the number of different individual machines in which the eggs of particular birds were set at different times during the hatching season. Thus, the 45 eggs of bird No. 375 during the whole season were set in 7 different incubators.

While Table I shows by illustrative cases that fertility and hatching quality of eggs are essentially different things it does not tell anything about what is the average relationship between these two phenomena or characteristics when large numbers of birds are taken into account. Granting that fertility does not necessarily denote superior hatching quality there still remains the question: what in general, or on the average, is the relation between the fertility of a hen's eggs on the one hand and their hatching quality on the other hand? On the average will hens or flocks of hens showing relatively high fertility of eggs also show relatively high hatches from the fertile eggs? In order to answer this question it is necessary to determine numerically and exactly the average relation or, as it is technically called, the *correlation* between these characters fertility and hatching quality of eggs. The nature of the problem here must be clearly grasped if what follows is to be intelligible. The first thought which comes to the reader of the questions just propounded is that the proportion of fertile eggs hatched will depend altogether on how they are incubated and that the answer to be given to the question will be determined by this obvious fact.

It is quite true that the methods and vicissitudes of incubation determine what proportion of fertile eggs shall hatch, but this has nothing to do with the answer to the question. Suppose the eggs of 50 hens to be taken for incubation. It is absolutely certain that *whatever the method of incubation*—whether it be such as to lead to good or poor average hatches—the fertile eggs of some *individual* hens among the 50 will produce more chickens than will the fertile eggs of other individual hens. Our problem is to learn whether, on the average, these hens which show relatively high hatches also show relatively high fertility of eggs. With this problem the method of incu-

TABLE II.

*Showing the Correlation between Fertility and Hatching Quality of Eggs. Records for Hatching Season of 1908.*

| Per Cent. Infertile. | Per Cent. of Fertile Eggs Hatched. | | | | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–3 | 4–7 | 8–11 | 12–15 | 16–19 | 20–23 | 24–27 | 28–31 | 32–35 | 36–39 | 40–43 | 44–47 | 48–51 | 52–55 | 56–59 | 60–63 | 64–67 | 68–71 | 72–75 | 76–79 | 80–83 | 84–87 | 88–91 | |
| 0– 3 | – | – | – | – | – | 1 | – | – | – | 1 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 3 |
| 4– 7 | – | – | – | – | – | – | – | 1 | 2 | 2 | 1 | 1 | 1 | – | 2 | 2 | – | 1 | 1 | – | – | – | 1 | 14 |
| 8–11 | – | – | – | 1 | 1 | 1 | 2 | 1 | – | – | – | 2 | – | 1 | – | 1 | 1 | 1 | – | – | – | – | – | 12 |
| 12–15 | – | – | – | 1 | – | 2 | 5 | – | 3 | – | 3 | 1 | 1 | 4 | 2 | 1 | – | – | – | – | – | – | – | 23 |
| 16–19 | – | – | – | – | 3 | – | 1 | 1 | 2 | 1 | 1 | 1 | 1 | – | 1 | – | – | – | 1 | – | – | – | – | 13 |
| 20–23 | – | – | – | 1 | 1 | – | 1 | 1 | 1 | – | 2 | 1 | – | – | – | – | – | – | 1 | – | – | – | – | 9 |
| 24–27 | 1 | – | – | – | – | 1 | – | 3 | – | – | – | 1 | – | – | – | – | – | 1 | – | – | – | – | – | 7 |
| 28–31 | – | – | – | 1 | – | – | – | – | – | 2 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 4 |
| 32–35 | – | – | – | – | – | – | – | 1 | – | 2 | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | 5 |
| 36–39 | 1 | – | – | – | – | 1 | – | – | 1 | – | 2 | – | – | – | – | – | – | – | – | – | – | – | – | 5 |
| 40–43 | 1 | 1 | 1 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 4 |
| 44–47 | – | – | – | – | 1 | 1 | – | – | 1 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | 4 |
| 48–51 | – | – | – | – | – | – | – | 2 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 4 |
| 52–55 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 56–59 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 60–63 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 64–67 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 68–71 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 72–75 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 76–79 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 80–83 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Totals..... | 5 | 2 | 1 | 4 | 6 | 7 | 9 | 10 | 12 | 8 | 9 | 8 | 6 | 5 | 5 | 5 | 2 | 2 | 3 | 0 | 0 | 0 | 1 | 110 |

bation or its general average result has nothing whatever to do, provided that large numbers of eggs are dealt with and all are incubated by the *same* method. It is with the average differences in the fertility and hatching of the eggs of individual hens all treated in the same way that we have to do.

From the way in which our records are taken it is easiest to use as a measure of fertility the percentage of infertile eggs in the total number of eggs set and as the measure of hatching quality the percentage of fertile eggs which were hatched. Now in order to determine the correlation between these two variables, per cent. of eggs infertile on the one hand and per cent. of fertile eggs hatched on the other hand, it is necessary to prepare a table which shall show for each bird included in our records the performance in respect to each of these variables. Having prepared such a table it is possible by the application of proper mathematical methods to deduce an exact numerical measure of the degree of correlation exhibited.*

* For references to the literature describing these mathematical methods see Me. Agr. Expt. Stat. Bulletin 166, p. 64.

TABLE III.

*Showing the Correlation between Fertility and Hatching Quality of Eggs. Records for Hatching Season of 1908. Pullets and Yearling Hens combined.*

| Per Cent. of Fertile Eggs Hatched. | Per Cent. Infertile. | | | | | | | | | | | | | | | | | | | | | Totals... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | 95–100 | 100–105 | |
| 0– 5 | 2 | 1 | 1 | – | 2 | – | – | – | – | 1 | – | – | 1 | – | 1 | – | – | – | – | 1 | 1 | – | 11 |
| 5– 10 | 1 | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | 3 |
| 10– 15 | 1 | 1 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 3 |
| 15– 20 | 3 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 4 |
| 20– 25 | 2 | – | 1 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 4 |
| 25– 30 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 30– 35 | 7 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 8 |
| 35– 40 | 2 | – | 1 | – | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 5 |
| 40– 45 | 9 | 2 | 2 | – | – | 2 | 1 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 17 |
| 45– 50 | 4 | 1 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 6 |
| 50– 55 | 8 | 2 | 1 | 2 | 2 | 1 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 17 |
| 55– 60 | 8 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 9 |
| 60– 65 | 10 | 2 | 1 | – | – | 2 | – | 1 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | 17 |
| 65– 70 | 4 | 1 | 1 | – | – | – | 1 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 8 |
| 70– 75 | 5 | 2 | 1 | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 10 |
| 75– 80 | 4 | 2 | 1 | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | 10 |
| 80– 85 | 3 | 1 | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 6 |
| 85– 90 | 1 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 90– 95 | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 95–100 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 100–105 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 2 |
| Totals..... | 77 | 18 | 11 | 6 | 7 | 6 | 7 | 1 | 2 | 2 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 2 | 1 | 1 | 1 | – | 146 |

Such correlation tables for the 1908 and 1909 records are exhibited as Tables II to V inclusive.

The data for 1909 are given in three tables, while those for 1908 are given in one. In the first of the 1909 tables (Table III) both pullets and yearling hens are included. Table IV gives the 1909 pullet records separately and Table V the 1909 yearling hen records separately. Owing to an oversight, one more bird is included in the combined than in the separate tables. This makes no difference in the results.

Even from the most casual examination of these tables it is apparent that there is a general tendency for birds showing a relatively high percentage of *infertile* eggs (i. e., *low* percentage of *fertile* eggs) to show a relatively low percentage of fertile eggs hatched and *vice versa*. Thus, if one examines the first three rows of Table II it will be seen that the majority of the

TABLE IV.

*Showing the Correlation between Fertility and Hatching Quality of Eggs. Records for Hatching Season of 1909. Pullets only.*

| Per Cent. of Fertile Eggs Hatched. | Per Cent. Infertile. | | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | 95–100 | | |
| 0– 5 | 2 | 1 | 1 | – | 1 | – | – | – | – | – | – | – | 1 | – | 1 | – | – | – | – | 1 | | 8 |
| 5– 10 | 1 | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 3 |
| 10– 15 | – | 1 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | | | 2 |
| 15– 20 | 2 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | | | 3 |
| 20– 25 | 1 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 2 |
| 25– 30 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 1 |
| 30– 35 | 5 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 6 |
| 35– 40 | 1 | – | 1 | – | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 4 |
| 40– 45 | 4 | – | 2 | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | | | 8 |
| 45– 50 | 4 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 4 |
| 50– 55 | 4 | – | – | 2 | 1 | 1 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | | | 9 |
| 55– 60 | 6 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | | | 7 |
| 60– 65 | 6 | – | 1 | – | – | 1 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | | | 9 |
| 65– 70 | 1 | 1 | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | | | 3 |
| 70– 75 | 3 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 4 |
| 75– 80 | 4 | 2 | – | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | | | 8 |
| 80– 85 | 1 | 1 | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 4 |
| 85– 90 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 90– 95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 0 |
| 95–100 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | | 1 |
| 100–105 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | | 1 |
| Totals..... | 46 | 8 | 8 | 5 | 5 | 3 | 5 | 1 | 1 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | | 87 |

individuals in those rows fall towards the right hand side of the table. That is, these are birds hatching relatively high percentages of fertile eggs. But, at the same time, these first three rows denote a relatively low percentage of infertile eggs or, stated the other way, denote that a high percentage of the eggs were fertile. While the existence of this general trend showing a correlation between fertility and hatching quality is evident on inspection, the degree or amount of the trend cannot be so told. What is necessary is to get some single constant which shall in one figure give a measure of the general trend exhibited by the table. Such a constant is afforded in the so-called *coefficient of correlation* which can be evaluated from the table by appropriate methods. Calculating this coefficient from each of the two tables and denoting it by the usual symbol $r$ we have:

TABLE V.

*Showing the Correlation between Fertility and Hatching Quality of Eggs. Records for Hatching Season of 1909. Yearling Hens only.*

| Per Cent. of Fertile Eggs Hatched. | Per Cent. Infertile. | | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | 95–100 | 100–105 | |
| 0– 5 | 1 | – | – | – | 1 | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 | 3 |
| 5– 10 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 10– 15 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 15– 20 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 20– 25 | 1 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 25– 30 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 30– 35 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 35– 40 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 40– 45 | 5 | 2 | – | – | – | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 9 |
| 45– 50 | 1 | 1 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 3 |
| 50– 55 | 4 | 2 | 1 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 8 |
| 55– 60 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 60– 65 | 4 | 2 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 8 |
| 65– 70 | 3 | – | 1 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | 5 |
| 70– 75 | 2 | 2 | – | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 6 |
| 75– 80 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 2 |
| 80– 85 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 85– 90 | 1 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 90– 95 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 95–100 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 100–105 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Totals.... | 30 | 10 | 3 | 1 | 2 | 3 | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 58 |

From 1908 records (Table II) $r = -0.417 \pm 0.053$. Pullets only.

From 1909 records (Table III) $r = -0.142 \pm 0.055$. Pullets and yearling hens combined.

From 1909 records (Table IV) $r = -0.127 \pm 0.071$. Pullets only.

From 1909 records (Table V) $r = -0.139 \pm 0.087$. Yearling hens only.

Translated into words these coefficients mean that the records under discussion show in general that there is a definite and significant negative correlation between the percentage of eggs infertile and the percentage of fertile eggs which are hatched.

It will at once be noted that the coefficients do not show the same value in both years. In the 1908 records the correlation is approximately 42 per cent of perfect correlation. Perfect correlation would indicate an absolute and unvarying relationship between the two phenomena. That is to say, if the corre-

lation were perfect high fertility would invariably denote high hatching quality and *vice versa*. The relationship actually exhibited in the 1908 records is about half way between such perfect correlation, and the entire absence of correlation in which event the two phenomena are not in any way related. The 1909 records show a considerably smaller correlation than those for 1908. Here, however, the coefficient for the combined data is approximately 2.6 times its probable error and hence would have to be regarded, even when considered by itself as almost certainly significant. When the 1909 pullets and yearling hens are treated separately the coefficients are slightly smaller than when they are combined, and with the reduction in the number of entries in the tables the probable errors are increased in value. In both of these cases, however, the sign of the coefficient remains negative. Neither of these coefficients (1909 pullets only and yearling hens only) could be considered certainly significant in comparison with its probable error when taken by itself. Taking both years together there is no doubt as to the conclusion that, *so far as the present data indicate, there is a small but still sensible correlation between fertility and hatching quality of eggs. In the long run, or on the average, it is to be expected on the basis of this result that if a hen under a given set of conditions produces eggs high in fertility the fertile eggs will also run high in hatching quality, and vice versa.* It is to be understood that no wider generality is claimed for this conclusion than arises from the data on which it is based.

It is not unlikely that the absolute degree of the correlation between fertility and hatching quality of eggs may be different for different breeds. The present data show that this correlation is different for different conditions of housing, treatment, etc. The further analysis of the precise effect of these factors present interesting problems for further work in this connection. It seems unlikely, however, that under any circumstances the correlation would be turned about so that high fertility was associated *regularly* with low hatching quality and *vice versa*.

## Variation in Fertility and Hatching Quality of Eggs.

From the figures which are given in Tables II to V inclusive, it is possible to get some exact information regarding the degree and character of variability shown by the pullets under discussion in respect to fertility and hatching quality of eggs. The important variation constants for these two characters are given in Table VI.

TABLE VI.

*Constants of Variation in Fertility and Hatching Quality of Eggs. Calculations from the Data of Tables II-V inclusive.*

| Character. | Mean or average. | Standard deviation. (A measure of variation.) |
|---|---|---|
| Per cent. of eggs infertile, 1908 | 21.71±0.96 | 15.00±0.68 |
| " " " " " 1909, pullets and yearling hens combined | 14.14±1.15 | 20.56±0.81 |
| Per cent. of eggs infertile, 1909, pullets only | 13.65±1.38 | 19.10±0.98 |
| " " " " " 1909, yearling hens only | 15.09±2.01 | 22.65±1.42 |
| " " " fertile eggs hatched, 1908 | 37.24±1.16 | 17.99±0.82 |
| " " " " " 1909, pullets and yearling hens combined | 50.68±1.35 | 24 16±0.95 |
| Per cent. of fertile eggs hatched, 1909, pullets only | 47.67±1.80 | 24.92±1.27 |
| " " " " " 1909, yearling hens only | 54.48±1.94 | 21.91±1.37 |

From this table the following points are to be noted:

1. The mean or average percentage of infertile eggs shown in the breeding records of the 1908 group of birds is approximately 22. This is an unduly high percentage of infertility. It is to be explained, however, by the fact, pointed out above, that the breeding work in that year was done under unsuitable housing conditions. In 1909 the average percentage of infertility taking all birds of the year together, was approximately 14. This reduction of about 8 per cent in the number of infertile eggs is directly attributable to the improvement in housing conditions. The figure for 1909 represents a very fair average condition of fertility, taking the whole breeding season through, and remembering that this represents returns on from 5000 to 6000 incubated eggs. If the early portion of the breeding season were left out of account the average percentage of infertility would be considerably reduced below 14, the figure given.

2. The mean or average percentage of fertile eggs hatched in the 1908 season is seen to be approximately 37. This again is an unduly low value. One has a right to expect a considerably better hatching quality of eggs than this. Like the poor average record for fertility it is, however, to be explained chiefly by the unsuitable housing conditions under which the birds were kept in that year, and in small part by the fact that only pullet records are available. This is shown to be the case by the 1909 figures where we have the percentage of fertile eggs hatched increased to 51 per cent in round numbers taking all the birds of the season together. This last figure would again be increased if the records of the early part of the breeding season were omitted. It is believed, furthermore, that by selection of breeding stock on the basis of hatching records it may be possible to improve the average hatching quality of eggs still more, (cf. discussion of this point in summary).

3. The degree of absolute variability as measured by the standard deviation is seen to be in all but one case (1909 yearling hens only) somewhat greater in the case of hatching quality than in the case of fertility. The standard deviation is a precise measure of the degree to which a group of individuals conform to a type with respect to any character under investigation. The closer to type a given lot of individuals run the smaller will be the standard deviation exhibited by that lot. On the other hand the more widely the individuals are scattered about the type the larger will be the standard deviation. It is not necessary in this place to go into the matter of how the standard deviation is calculated. It suffices to say that it is a scientifically accurate measure of the degree of closeness to type.

4. While hatching quality appears from the present statistics to be absolutely a slightly more variable character than fertility, if we consider the degree of variation in proportion to the mean, the opposite is the case. This is shown if from Table IV the percentage which the standard deviation is in the mean is calculated for each of the two characteristics. Performing this operation the following results are obtained:

1908—Fertility: percentage of standard deviation in mean = 69.1%.

All birds, 1909—Fertility: percentage of standard deviation in mean = 145.4%.

Pullets only, 1909—Fertility: percentage of standard deviation in mean = 140.0%.

Hens only, 1909—Fertility: percentage of standard deviation in mean = 150.2%.

1908—Hatching quality, percentage of standard deviation in mean = 48.3%.

All birds, 1909—Hatching quality, percentage of standard deviation in mean = 47.7%.

Pullets only, 1909—Hatching quality, percentage of standard deviation in mean = 52.3%.

Hens only, 1909—Hatching quality, percentage of standard deviation in mean = 40.2%.

These figures show that in proportion to the mean of the characteristic, hatching quality is relatively much less variable than fertility. Both of the characters—fertility and hatching quality—are, so far as may be judged from the present statistics, highly variable as compared with other characters of poultry which have been studied in this connection.

5. From the data given in the preceding paragraph it appears that in proportion to the mean the fertility of eggs varied much more in 1909 than in 1908, while in respect to hatching quality the relative degree of variability was substantially the same in the two years. This would suggest that the difference in housing conditions of the two years had a much greater effect on the *variability* (as distinguished from the absolute average condition) of fertility than on that of hatching quality. This, however, can, in the light of the present data, be only a suggestion, the correctness of which must be tested by further work.

6. From the data of Table VI it appears that in 1909 the yearling hens were superior to the pullets in regard to both the average fertility and the average hatching quality of their eggs. The difference between the two groups in mean fertility is, however, hardly significant. More data are needed before any final conclusion as to the relative ability of pullets and yearling hens as breeders may be drawn.

### The Relation of the Hen to the Fertility of Eggs.

There is a rather common belief that when hatching eggs run low in fertility the fault is chiefly or entirely in the male bird which is with the flock. For some reason which is difficult to understand very little influence is attributed in the popular mind to the females in causing poor results of this kind, the belief rather being that the male bird has an almost exclusive influence in determining fertility of eggs. It seems somewhat remarkable that this notion of the predominant influence of the male bird in determining the fertility of eggs among poultry should be so widespread, in view of the fact that the popular belief with reference to other domestic animals is exactly the opposite. For example, in cattle and horse breeding the failure of the female to become pregnant (the equivalent in part of the fertilization of the egg in poultry) is commonly attributed to some defect in the female rather than in the male. The standpoint which the known facts of biology lead one to take is that in all bisexual animals the influence of the two sexes is in general equal in determining whether any given egg shall or shall not be fertilized. That is to say, there is on general grounds every reason to suppose that the infertility of eggs is as likely to be due to a defect of the female as to a defect of the male and *vice versa*. It seems desirable to determine with some precision whether this general statement is true for poultry or not. When the average fertility for a flock of hens runs low what proportion of this low fertility is to be attributed to the poor breeding performance of the hens and what proportion to the male birds? The practical importance of the question is obvious. If the man who is selling eggs for hatching can learn that one particular hen, for example, in his flock never produces a fertile egg, it will be greatly to the advantage of his trade to eliminate that bird from those which are producing his hatching eggs.

In order to bring out with completeness and precision the comparative influence of male and female birds on the fertility of eggs Tables VII and VIII have been prepared. These tables show for each breeding pen the following facts: (1) The band number of the cockerel which was placed in that pen.

TABLE VII.

*Percentage of Infertile Eggs Produced by Each of the Barred Plymouth Rock Pullets Making Complete Records in the Hatching Season of 1908. Arranged According to Pens and Cockerels.*

| Pen No. | Cockerel No. | | Band number and per cent. of *infertile* eggs for each pullet. (Band numbers are in brackets; percentages unbracketed.) | Average percentage of infertile eggs for each cockeral. |
|---|---|---|---|---|
| 5 | D | 70 | (19)24, (21)14, (358)32, (357)36, (393)9, (712)20 | 22.5 |
| 6 | D | 2 | (10)36, (27)8, (112)18, (160)42, (402)30, (705)34 | 28.0 |
| 7 | D | 60 | (29)29, (87)17, (352)14, (353)17, (717)19 | 19.2 |
| 8 | D | 32 | (61)21, (122)15, (357)14, (374)22, (381)4, (406)24 | 16.7 |
| 9 | D | 65 | (12)19, (18)48, (38)9, (172)27, (366)13, (367)21, (414)7 | 20.6 |
| 10 | D | 5 | (39)26, (66)12, (415)50, (438)45, (707)0 | 26.6 |
| 11 | D | 56 | (20)73, (118)12, (197)12, (407)18, (726)20 | 27.0 |
| 12 | D | 11 | (23)28, (428)20, (709)20, (730)31, (737)13 | 22.4 |
| 13 | D | 58 | (368)15, (431)10, (734)4 | 9.7 |
| 14 | D | 16 | (121)41, (152)11, (185)15, (224)11, (432)37, (731)23 | 23.0 |
| 15 | D | 61 | (52)53, (99)33, (168)5, (719)40, (736)14 | 29.0 |
| 16 | D | 35 | (129)48, (223)38, (382)8, (725)6, (728)12, (732)14 | 21.0 |
| 17 | D | 57 | (359)15, (389)29, (395)24, (743)82, (744)24 | 34.8 |
| 18 | D | 17 | (377)16, (401)16, (405)32, (410)3, (411)14, (774)14, (784)47 | 20.3 |
| 19 | D | 68 | (419)14, (422)15, (424)45, (745)41, (746)15 | 26.0 |
| 20 | D | 26 | (388)50, (397)6, (434)17, (441)33, (442)38, (749)4, (750)16, (752)6, (753)46, (757)10, (768)20, (770)10, (771)13 | 20.8 |
| 21 | D | 31 | (400)16, (408)16, (409)4, (443)6, (444)8, (447)5, (450)4.(758)19, (759)12, (761)8, (762)10, (763)5, (764)13, (765)3, (766)5. | 8.9 |

(2) The band number of each of the pullets placed in that pen. (3) The percentage of infertile eggs produced by each of these pullets. (4) In the last column of the table are given the average percentages of infertile eggs produced by all the hens running in each pen. These averages in the last column are, in other words, the only measures which it is possible to get of the relative ability of the individual cockerels in fertilizing eggs. They are pen or cockerel averages.

TABLE VIII.

*Percentage of Infertile Eggs Produced by Each of the Barred Plymouth Rock Pullets and Yearling Hens Making Complete Records in the Hatching Season of 1909. Arranged According to Pens and Cockerels.*

| Pen No. | Cockerel No. | Band number and per cent. of *infertile* eggs for each female. (Band numbers are in brackets; percentages unbracketed.) | Average percentage of infertile eggs for each cockerel |
|---|---|---|---|
| 2 | E 551 | (125)3, (184)31, (212)2, (255)22, (287)4, (304)12, (296)0, (327)1, (343)93, (350)3, (354)2, (361)30, (415)0, (419)32 | 16.7 |
| 3 | E 552 | (201)0, (204)0, (229)3, (231)2, (238)25, (241)8, (250)15, (251)12, (270)10, (272)3, (280)4, (293)63, (295)6, (310)17 | 12.0 |
| 4 | E 553 | (17)2, (92)36, (94)15, (186)21, (221)0, (239)6, (248)32, (258)0 (303)0, (334)34, (382)21, (388)2, (406)14, (449)3 | 13.2 |
| 5 | E 554 | (3)0, (18)3, (160)44, (208)0, (224)4, (226)2, (228)3, (237)3, (266)2, (278)10, (324)8, (333)8, (352)12, (405)27 | 9.0 |
| 6 | E 555 | (74)5, (114)25, (155)0, (183)17, (202)2, (209)0, (232)20, (249)0, (302)0, (323)97, (325)0, (326)2, (377)2, (403)71 | 17.2 |
| 7 | E 556 | (206)0, (207)5, (215)18, (225)14, (235)0, (257)20, (263)0, (276)4, (294)3, (385)12, (420)0, (422)7 | 6.9 |
| 11 | D* 56 | (1063)0, (1069)4, (1070)12, (1071)100, (1072)28, (1073)0, (1074)47, (1075)47, (1076)0, (1078)87, (1079)5, (1080)31, (1081)2, (1082)0, (1083)85 | 29.8 |
| 12 | D 11 | (1005)2, (1046)0, (1047)5, (1050)63, (1051)20, (1053)9, (1056)2, (1057)7, (1058)32, (1060)5, (1062)24, (1065)0, (1067)0, (1068)0 | 12.0 |
| 13 | D 58 | (1003)0, (1024)0, (1026)27, (1027)0, (1028)2, (1030)0, (1032)10, (1033)0, (1038)7, (1039)6, (1040)0, (1041)4, (1043)0, (1044)3, (1045)4, (E 427)0 | 3.9 |
| 14 | D 31 | (E 220)0, (1001)5, (1006)0, (1008)0, (1009)18, (1010)4, (1013)0, (1014)10, (1016)0, (1017)5, (1019)0, (1022)0, (1023)40 | 6.3 |

From these tables the following points are to be noted:

1. There is clearly a very great difference among different pullets in their ability to produce fertile eggs. The extent of such differences may be grasped by a detailed examination of the tables. Some examples on this point may be cited, taking Table VII first. In pen 9, one bird (No. 414) had only 7 per cent. of her eggs infertile. In the same pen, and hence with the same cockerel, another pullet (No. 18) had 48 per cent of her

* Males having band numbers prefixed by the letter D are cock birds, and those with the letter E are cockerels. Females having band numbers above 1000 are hens (hatched in 1907), all other females are pullets, (1908 hatch).

eggs infertile. It is difficult to see how anyone can attribute the infertility of the eggs of No. 18 to the cockerel (No. 65) when in the same pen No. 414 made such a fine record in respect to fertility. To take another example, in pen 10 No. 707 produced no infertile eggs. Every egg which this pullet produced between February and June—30 in all—was fertile, yet in this same pen and with the same cockerel, pullet No. 415 had 50 per cent and pullet No. 438 had 45 per cent of their eggs infertile. If one attempts to account for the poor performance of Nos. 415 and 438 in regard to fertility as due to some inherent fault in cockerel No. 5 he is at once confronted by the perfect record of fertility made by No. 707. In pen 11 again, there are wide extremes in regard to fertility. Pullet No. 197 had but 12 per cent of her eggs infertile while with the same cockerel pullet No. 20 had 73 per cent of her eggs infertile. In pen 18 pullet No. 410 had but 3 per cent of her eggs infertile, while pullet No. 784 had 47 per cent infertile. Anyone who will take the trouble to study Table VII carefully will find just as wide extremes of fertility shown by the pullets in other pens.

The same thing is apparent in the data of Table VIII showing that this result is not something peculiar to one single season or set of birds. Thus in pen 11 there were four birds (1063, 1073, 1076, 1082) that produced no infertile eggs throughout the breeding season, though the total numbers of eggs laid by these birds during the season were: 23, 26, 26, 36. Yet in this same pen 1071 had 100 per cent. and 1078, 87 per cent. of infertile eggs.

The facts set forth in these tables make it absolutely certain that there are wide differences in the breeding ability (measured by fertility of eggs) of different females, which are quite independent of the relative ability of the male birds running with the females as breeders.

2. An examination of the last column of the table indicates that there was proportionately much less variability among the cockerels used as breeders than among the pullets, in respect to their influence in determining the fertility of eggs. In 1908 with the exception of three pens (Nos. 13, 17 and 21) the fertility performance of the cockerels runs very evenly. Furthermore, a study of the table shows that in two out of these three

widely varying pens the deviation is to be explained as the result of too few hens on which to base a fair average. Consequently there is an overwhelming influence on the average of the performance of one exceptionally good or one exceptionally poor pullet. Thus in the case of pen 13 (1908) the cockerel average of 9.7 per cent. of infertile eggs is based on the performance of only three birds, and one of these (No. 734) made (for that year) the very exceptional record of only 4 per cent. infertile eggs. Similarly in pen 17 the very poor cockerel record of 34.8 per cent. infertile eggs is largely due to the influence of one particular pullet (No. 743) 82 per cent. of whose eggs were infertile. When an average is based upon but 5 cases as in pen No. 17 and one of these deviates so widely from the others as does the record of 743 it is not remarkable that the general average is affected.

The pen averages do not run quite so smoothly in 1909 as in 1908. This is in part to be acounted for by the fact that in 1908 only young birds (pullets and cockerels) are included in the table, whereas in 1909 pens 11-14 inclusive were made up of birds hatched in 1907. In general the indications from both tables are that the male birds used in these two years were a fairly even lot so far as breeding ability is concerned.

3. The effect of the closed, heated house No. 1 in reducing the fertility of eggs is brought out in two ways by these tables. It is clearly shown in the data of Table VII alone. Breeding pens 20 and 21 (1908) were in the curtain front house No. 2. Breeding pens 5 to 19 inclusive of that same year were in house No. 1. The difference in the average infertility of the eggs from the two houses is shown in the following figures.

Average from House No. 1 (pens 5-19 inclusive)=23.1%.

Average from House No. 2 (pens 20 and 21)=14.8%.

The bad effect of house No. 1 on fertility is, of course, further shown by comparison of the last columns in Tables VII and VIII, the first 15 entries in this column in Table VII representing data from house No. 1 and Table VIII data from house No. 2.

It is noteworthy that the average fertility shown by the two breeding pens which were in the curtain front house No. 2 in 1908 (pens 20 and 21) is very nearly the same as the average fertility from all pens in the same house in 1909 (14.8% and

14.14% from Table VI. This indicates again how direct and important an influence housing conditions have upon the fertility of the eggs of breeding birds.

4. It is of some interest to compare the fertility records of the same male bird in his first and second breeding years, though the amount of data available for such comparison in the present statistics is small. The four birds D 56, D 11, D 58, and D 31 appear in both Table VII and Table VIII. Their records of average pen fertility of eggs in the two years are as follows:

*Average Percentage of Infertile Eggs.*

| Male bird. | 1908. (Cockerel year.) | 1909. (Cock year.) |
|---|---|---|
| D 56 | 27.0% | 29.8% |
| D 11 | 22.4% | 12.0% |
| D 58 | 9.7% | 3.9% |
| D 31 | 8.9% | 6.3% |

Of these four birds only one (D 31) did his breeding under identical housing conditions in the two years. In this case there is practically no difference in the average fertility. In two cases (D 11 and D 58) there is a very considerable reduction in the average percentage fertility, but this is probably to be explained almost entirely as the result of the action of the better housing conditions of 1909 on the breeding birds, particularly the females. D 56 has a worse record for 1909 than for 1908, but this bad average is due very largely to the effect of three hens, viz: 1071, 1078, and 1083, with 100, 87, and 85 per cent of infertile eggs respectively. This is a heavy handicap in an average based on only 15 birds.

5. An examination of these tables and of the detailed hatching records on which they are based emphasizes the value of trap nesting breeding hens during the breeding season at least, particularly if one is to engage in selling eggs for hatching. A study of the records shows that it would have been possible to have thrown out early in the hatching season such poor performers as, for example Nos. 18, 415, 438, 784 in 1908, and 1071, 1078, 1083, 160 and 403 in 1909. These birds were

TABLE IX.

*Showing the Correlation between Fertility of Eggs and Winter (November 1 to March 1) Egg Production. Data for 1908.*

| Winter Egg Production. | Per Cent. Infertile. | | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-3 | 4-7 | 8-11 | 12-15 | 15-19 | 20-23 | 24-27 | 28-31 | 32-35 | 36-39 | 40-43 | 44-47 | 48-51 | 52-55 | 56-59 | 60-63 | 64-67 | 68-71 | 72-75 | 76-79 | 80-83 | |
| 0- 5 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 5–10 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 10–15 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 15–20 | – | 1 | 2 | – | – | – | – | – | – | – | 1 | 1 | 1 | – | – | – | – | – | – | – | – | 6 |
| 20–25 | 1 | – | 1 | 1 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 5 |
| 25–30 | – | 1 | 1 | 5 | 3 | 1 | 1 | 1 | 1 | 1 | – | – | 1 | – | – | – | – | – | – | – | – | 16 |
| 30–35 | 1 | 4 | 1 | 6 | 1 | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 15 |
| 35–40 | – | 3 | – | 2 | 2 | – | – | – | 1 | 1 | 1 | 1 | – | – | – | – | – | – | 1 | – | – | 12 |
| 40–45 | – | 1 | 2 | 1 | 2 | 2 | 1 | – | 1 | – | – | 1 | – | 1 | – | – | – | – | – | – | – | 12 |
| 45–50 | – | – | 1 | 1 | 3 | 1 | 1 | – | 1 | 1 | 1 | – | 1 | – | – | – | – | – | – | – | – | 11 |
| 50–55 | – | 3 | – | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 5 |
| 55–60 | – | – | 3 | 3 | – | 1 | 1 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | 1 | 11 |
| 60–65 | 1 | 1 | – | 1 | – | – | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 5 |
| 65–70 | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| 70–75 | – | – | – | 1 | – | 1 | – | – | – | 1 | 1 | – | 1 | – | – | – | – | – | – | – | – | 5 |
| 75–80 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 80–85 | – | – | 1 | 1 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 3 |
| 85–90 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 90–95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 95–100 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Totals..... | 3 | 14 | 12 | 23 | 13 | 9 | 7 | 4 | 5 | 5 | 4 | 4 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 110 |

only allowed to stay in the breeding pens throughout the season in order to learn just how poor a record they would make for the purposes of the present study. The principle should be clearly recognized that some hens are "shy breeders" just as are some cows. Any method by which such birds can be thrown out and prevented from increasing the number of eggs which it takes in practical work to produce a living chick will be useful and profitable.

## The Relation of Winter Egg Production to the Fertility of Eggs.

Admitting the fact brought out in Tables VII and VIII that there are great individual differences among different pullets and hens in respect to their ability to produce fertile eggs, the further problem is raised as to what influences are responsible for these differences. What underlies the fact that one hen in a breeding pen will have say 50 per cent. of her eggs infertile while another hen in the same pen will have none of her eggs

TABLE X.

*Showing the Correlation between Fertility of Eggs and Winter (November to March) Egg Production. Hatching Season of 1909. Pullets and Yearling Hens Combined.*

| Per Cent. Infertile. | Winter Egg Production. | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | |
| 0– 5 | 6 | 2 | 4 | 8 | 3 | 4 | 13 | 5 | 9 | 1 | 6 | 3 | 6 | 2 | 1 | 3 | 1 | – | – | 77 |
| 5–11 | – | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 3 | – | 2 | 2 | – | – | 1 | – | – | – | – | 18 |
| 10–15 | – | – | 1 | – | 2 | – | 1 | – | – | – | 1 | 1 | 1 | 3 | – | – | – | – | 1 | 11 |
| 15–20 | – | – | – | – | – | – | – | 1 | – | 2 | 1 | – | – | 1 | – | 1 | – | – | – | 6 |
| 20–25 | 1 | – | – | – | – | 2 | – | – | 1 | 1 | – | – | – | 2 | – | – | – | – | – | 7 |
| 25–30 | – | – | – | 2 | 1 | – | – | – | 2 | – | – | – | – | – | 1 | – | – | – | – | 6 |
| 30–35 | – | 2 | – | 1 | – | – | 1 | – | – | 1 | – | 1 | – | 1 | – | – | – | – | – | 7 |
| 35–40 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 40–45 | – | – | – | 1 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 45–50 | – | – | – | 1 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 50–55 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 55–60 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 60–65 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | 1 | – | 1 | – | – | – | 3 |
| 65–70 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 70–75 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 75–80 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 80–85 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 85–90 | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 90–95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 1 |
| 95–100 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 |
| 100–105 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Totals..... | 7 | 5 | 8 | 15 | 7 | 8 | 20 | 10 | 15 | 6 | 9 | 7 | 7 | 8 | 6 | 6 | 1 | 0 | 1 | 146 |

infertile? There are undoubtedly a large number of factors concerned in this matter. The only hope of ever determining what all these factors are and what is the relative influence of each one is to make an *analytical* study of the facts. One factor must be taken at a time and its relative influence determined. Proceeding in this way there is reason to believe that in time it will be possible to arrive at a more adequate understanding of the matter than we now have.

The opinion is very commonly expressed that the fertility of eggs during the hatching season, and in particular of pullets' eggs, depends very largely on the previous laying record of the bird producing the eggs. It is contended that if a bird has laid very heavily throughout the winter her eggs will not run so high in fertility, on the average, as will those of a bird whose winter production has not been so great. From what has gone before it must be clear to the reader that the only way to make an exact test of the truth of this assertion, or in general to find

TABLE XI.

*Showing the Correlation between Fertility of Eggs and Winter (November to March) Egg Production. Hatching Season of 1909. Pullets only.*

| Per Cent. Infertile. | Winter Egg Production. | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | | |
| 0– 5 | – | 1 | 4 | 1 | 1 | 7 | 4 | 6 | 1 | 5 | 3 | 6 | 2 | 1 | 3 | 1 | – | – | | 46 |
| 5–10 | – | – | – | 1 | – | 1 | 1 | 2 | – | 1 | 1 | – | – | 1 | – | – | – | – | | 8 |
| 10–15 | – | – | – | – | – | 1 | – | – | – | 1 | 1 | 1 | 3 | – | – | – | – | 1 | | 8 |
| 15–20 | – | – | – | – | – | – | 1 | – | 1 | 1 | – | – | 1 | – | 1 | – | – | | | 5 |
| 20–25 | – | – | – | – | 1 | – | – | 1 | 1 | – | – | – | 2 | – | – | – | – | – | | 5 |
| 25–30 | – | – | 1 | – | – | – | – | 1 | – | – | – | – | – | 1 | – | – | – | – | | 3 |
| 30–35 | 1 | – | – | – | – | 1 | – | – | 1 | – | 1 | – | 1 | – | – | – | – | – | | 5 |
| 35–40 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | | 1 |
| 40–45 | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | | 1 |
| 45–50 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 50–55 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 55–60 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 60–65 | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | 1 | – | – | – | | 2 |
| 65–70 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 70–75 | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | | 1 |
| 75–80 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 80–85 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 85–90 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | | 0 |
| 90–95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | | 1 |
| 95–100 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | | 1 |
| Totals.. | 1 | 1 | 5 | 2 | 2 | 12 | 7 | 10 | 5 | 7 | 6 | 7 | 8 | 6 | 6 | 1 | 0 | 1 | | 87 |

out the relative influence of this factor is to determine the degree of correlation which exists between winter production and fertility of eggs. Just as before, one must be sure that one understands the problem involved here. Will the individual hen which has laid heavily in the winter have on the average, or in the long run, a higher record for fertility during the hatching season than one that has not laid heavily, and *vice versa?* To answer this question it is necessary to construct a correlation table between the two variables—winter egg laying on the one hand and fertility of eggs on the other hand. If there is any influence of previous egg laying on fertility of eggs we shall expect to see it manifested in this table and in the measure of correlation which can be deduced therefrom.

Such correlation tables between fertility of egg and winter production for the 1908 and 1909 seasons are presented in

TABLE XII.

*Showing the Correlation between Fertility of Eggs and Winter (November to March) Egg Production. Hatching Season of 1909. Yearling Hens only.*

| Per Cent. Infertile. | Winter Egg Production. | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–50 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | |
| 0– 5 | 6 | 2 | 3 | 4 | 2 | 3 | 6 | 1 | 3 | – | – | – | 30 |
| 5–10 | – | 1 | 2 | 1 | – | 1 | 2 | – | 1 | – | 1 | 1 | 10 |
| 10–15 | – | – | 1 | – | 2 | – | – | – | – | – | – | – | 3 |
| 15–20 | – | – | – | – | – | – | – | – | – | 1 | – | – | 1 |
| 20–25 | 1 | – | – | – | – | 1 | – | – | – | – | – | – | 2 |
| 25–30 | – | – | – | 1 | 1 | – | – | – | 1 | – | – | – | 3 |
| 30–35 | – | 1 | – | 1 | – | – | – | – | – | – | – | – | 2 |
| 35–40 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 40–45 | – | – | – | 1 | – | – | – | – | – | – | – | – | 1 |
| 45–50 | – | – | – | 1 | – | – | – | 1 | – | – | – | – | 2 |
| 50–55 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 55–60 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 60–65 | – | – | – | – | – | – | – | 1 | – | – | – | – | 1 |
| 65–70 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 70–75 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 75–80 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 80–85 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 85–90 | – | – | 1 | 1 | – | – | – | – | – | – | – | – | 2 |
| 90–95 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 95–100 | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 100–105 | – | – | – | – | – | 1 | – | – | – | – | – | – | 1 |
| Totals... | 7 | 4 | 7 | 10 | 5 | 6 | 8 | 3 | 5 | 1 | 1 | 1 | 58 |

Tables IX to XII inclusive. These tables have been constructed by taking for each one of the birds under discussion the sum of the eggs laid by her in the months of November, December, January and February (winter egg-production) as one variable and the percentage of infertile eggs out of the total number of the same bird's eggs set during the hatching season as the other variable. Table IX gives the data for 1908 and Tables X, XI and XII those for 1909. Just as before the 1909 data are given first for pullets and yearling hens combined and then for each of these groups separately.

Examining these tables it is seen at once that there is no such evident correlation between the two characters as there was in the case of fertility and hatching quality of eggs. If there is any sensible influence of winter egg production on the fertility of eggs it obviously cannot be a very marked one. The individuals are apparently scattered over the table a good deal at random. There is no general trend of the statistics evident to the eye to indicate a close relationship between these phenomena. However, as has been seen before, the only way to determine the nature and degree of relationship is to calculate the coefficient of correlation between the variables. Doing this for Tables IX to XII inclusive we get the following results.

Coefficient of correlation between winter egg production and percentage of infertile eggs during the breeding season:

1908. $r = 0.077 \pm 0.064$. Pullets only.

1909. $r = -0.032 \pm 0.056$. Pullets and yearling hens combined.

1909. $r = 0.108 \pm 0.072$. Pullets only.

1909. $r = 0.009 \pm 0.089$. Yearling hens only.

From these values it is apparent that *the present statistics indicate no correlation whatever between winter egg production and fertility of eggs during the hatching season.* The correlation coefficient itself is not sensibly larger than its probable error in either year and hence cannot be regarded as significantly different from zero. A hen with a very high winter production is on the average no more likely to have her eggs run low in fertility than is a hen whose winter production has been lower, and *vice versa.* As before no wider generality is claimed for this result than arises from the statistics upon which it is based. All that is asserted is simply that when very careful records were kept during the whole hatching season for over 200 birds and over 10,000 eggs the returns show no relation whatever between winter laying and fertility of eggs.

TABLE XIII.

*Showing the Correlation between the Hatching Quality of Eggs and Winter (November to March) Egg Production. Hatching Season of 1908.*

| Winter Egg Production. | Per Cent. of Fertile Eggs Hatched. | | | | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-3 | 4-7 | 8-11 | 12-15 | 16-19 | 20-23 | 24-27 | 28-31 | 32-35 | 36-39 | 40-43 | 44-47 | 48-51 | 52-55 | 56-59 | 60-63 | 64-67 | 68-71 | 72-75 | 76-79 | 80-83 | 84-87 | 88-91 | |
| 0- 5 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 5-10 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 10-15 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 15-20 | – | – | 1 | – | 1 | 1 | – | 1 | – | – | – | – | – | – | – | 1 | 1 | – | – | – | – | – | – | 6 |
| 20-25 | – | – | – | – | 1 | – | – | – | – | 1 | – | 1 | – | 1 | – | – | – | 1 | – | – | – | – | – | 5 |
| 25-30 | 1 | – | – | – | – | – | 1 | 2 | 2 | 2 | 2 | – | 1 | 2 | 1 | 1 | – | – | 1 | – | – | – | – | 16 |
| 30-35 | – | – | – | – | – | – | 1 | – | 2 | 2 | 2 | 2 | 2 | 1 | 1 | – | 1 | – | – | – | – | – | 1 | 15 |
| 35-40 | 1 | 1 | – | – | 1 | 1 | 1 | – | 1 | 1 | 1 | 1 | 1 | – | – | 2 | – | – | – | – | – | – | – | 12 |
| 40-45 | – | 1 | – | – | 1 | 1 | – | 3 | – | 1 | 1 | 1 | – | 1 | 2 | – | – | – | – | – | – | – | – | 12 |
| 45-50 | 1 | – | – | – | – | 1 | 2 | 1 | 1 | 1 | 1 | – | 1 | – | 1 | – | – | – | 1 | – | – | – | – | 11 |
| 50-55 | – | – | – | – | 1 | – | – | 1 | 1 | – | – | 1 | – | – | – | – | – | – | 1 | – | – | – | – | 5 |
| 55-60 | 1 | – | – | 1 | 1 | 1 | 2 | – | – | – | 1 | 1 | 1 | – | – | 1 | – | 1 | – | – | – | – | – | 11 |
| 60-65 | – | – | – | – | – | 2 | – | – | 3 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 5 |
| 65-70 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 70-75 | 1 | – | – | – | – | – | 1 | 1 | – | – | 1 | 1 | – | – | – | – | – | – | – | – | – | – | – | 5 |
| 75-80 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 80-85 | – | – | – | 2 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 3 |
| 85-90 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 90-95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 95-100 | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Totals... | 5 | 2 | 1 | 4 | 6 | 7 | 9 | 10 | 12 | 8 | 9 | 8 | 6 | 5 | 5 | 5 | 2 | 2 | 3 | 0 | 0 | 0 | 1 | 110 |

## Relation Between Winter Egg Production and Hatching Quality of Eggs.

It has been seen that the statistics show no relation between winter egg laying and the fertility of eggs subsequently produced in the breeding season. This result at once suggests the further question as to whether the same thing is true in regard to hatching quality of eggs. Will the hen that has laid heavily during the winter produce on the average more or fewer chickens from a given number of fertile eggs than will a hen that has not laid heavily during the winter? It is apparent that again this is a problem in correlation. A table must be prepared and the correlation coefficient found between the two variables winter (November 1 to March 1) egg production on the one hand, and per cent. of fertile eggs hatched on the other hand. Such correlation tables for the two years 1908 and 1909 are shown in Tables XIII to XVI inclusive. The 1909 data are given in three tables as in preceding cases.

TABLE XIV.

*Showing the Correlation between the Hatching Quality of Eggs and Winter (November to March) Egg Production. Hatching Season of 1909. Pullets and Yearling Hens combined.*

| Per Cent. of Fertile Eggs Hatched. | Winter Egg Production. | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | |
| 0– 5 | – | – | – | 1 | – | 2 | 2 | 1 | – | 1 | – | – | 1 | 3 | – | – | – | – | – | 11 |
| 5–10 | – | – | – | – | – | – | – | 1 | 1 | 1 | – | – | – | – | – | – | – | – | – | 3 |
| 10–15 | – | – | – | – | – | – | 1 | 1 | – | – | – | – | – | – | 1 | – | – | – | – | 3 |
| 15–20 | – | – | – | – | – | – | 1 | – | – | – | 1 | – | 1 | 1 | – | – | – | – | – | 4 |
| 20–25 | 1 | 1 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 1 | – | – | – | 4 |
| 25–30 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 |
| 30–35 | – | – | – | 1 | – | – | 2 | – | 2 | 1 | – | – | – | – | 1 | – | 1 | – | – | 8 |
| 35–40 | – | – | – | – | 1 | 1 | – | – | 2 | – | – | 1 | – | – | – | – | – | – | – | 5 |
| 40–45 | 1 | – | 1 | 4 | 1 | 1 | 2 | – | 2 | – | 1 | 1 | – | 1 | 2 | – | – | – | – | 17 |
| 45–50 | – | – | 1 | – | 1 | – | 1 | – | – | – | – | 1 | 1 | – | – | 1 | – | – | – | 6 |
| 50–55 | 1 | – | – | 1 | 1 | – | 5 | 4 | 1 | – | 1 | – | – | 1 | 1 | 1 | – | – | – | 17 |
| 55–60 | 1 | 1 | 1 | – | – | 2 | – | – | 1 | – | 1 | – | 1 | – | – | 1 | – | – | – | 9 |
| 60–65 | 1 | – | 2 | 3 | – | – | 3 | – | 3 | – | 2 | 2 | 1 | – | – | – | – | – | – | 17 |
| 65–70 | 1 | – | 2 | – | – | 1 | – | 1 | 1 | – | 1 | 1 | – | – | – | – | – | – | – | 8 |
| 70–75 | – | 2 | – | 2 | – | 1 | 1 | – | 1 | 1 | – | – | – | 1 | – | – | – | – | 1 | 10 |
| 75–80 | – | – | – | 1 | 2 | – | 2 | 1 | – | 1 | – | 1 | 1 | 1 | – | – | – | – | – | 10 |
| 80–85 | – | – | – | 1 | 1 | – | – | 1 | – | – | 1 | – | – | – | 1 | 1 | – | – | – | 6 |
| 85–90 | – | 1 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 90–95 | – | – | 1 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | 2 |
| 95–100 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| 100–105 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 2 |
| Totals... | 7 | 5 | 8 | 15 | 7 | 8 | 20 | 10 | 15 | 6 | 9 | 7 | 7 | 8 | 6 | 6 | 1 | 0 | 1 | 146 |

From an examination of these tables it is at once apparent to the eye that there is a closer relation between the phenomena here dealt with than was exhibited in Tables IX to XII inclusive. The general trend of the entries, particularly in Table XIII, from the upper right hand corner to the lower left hand corner is unmistakable. As has been seen above (p. 116) in the case of the correlation between fertility and hatching quality this general sweep indicates that a sensible correlation will probably be found. Calculating the coefficients for Tables XIII to XVI the following results are obtained:

Correlation between winter egg production and per cent. of fertile eggs hatched:

1908: $r = -0.252 \pm 0.060$. Pullets only.

1909. $r = -0.133 \pm 0.055$. Pullets and yearling hens combined.

1909. $r = -0.010 \pm 0.072$. Pullets only.

1909. $r = -0.223 \pm 0.084$. Yearling hens only.

TABLE XV—*Showing the Correlation between the Hatching Quality of Eggs and Winter (November to March) Egg Production. Hatching Season of 1909. Pullets only.*

| Per Cent. of Fertile Eggs Hatched. | Winter Egg Production. | | | | | | | | | | | | | | | | | | | Totals... |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | |
| 0– 5 | – | – | – | 1 | – | – | 2 | – | – | 1 | – | – | 1 | 3 | – | – | – | – | – | 8 |
| 5–10 | – | – | – | – | – | – | – | 1 | 1 | 1 | – | – | – | – | – | – | – | – | – | 3 |
| 10–15 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 1 | – | – | – | – | 2 |
| 15–20 | – | – | – | – | – | – | – | – | – | – | 1 | – | 1 | 1 | – | – | – | – | – | 3 |
| 20–25 | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | 1 | – | – | – | 2 |
| 25–30 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 |
| 30–35 | – | – | – | – | – | – | 2 | – | 1 | 1 | – | – | – | – | 1 | – | 1 | – | – | 6 |
| 35–40 | – | – | – | – | 1 | 1 | – | – | 1 | – | – | 1 | – | – | – | – | – | – | – | 4 |
| 40–45 | – | – | – | 2 | – | – | 1 | – | – | – | 1 | 1 | – | 1 | 2 | – | – | – | – | 8 |
| 45–50 | – | – | – | – | – | – | 1 | – | – | – | 1 | 1 | – | – | – | 1 | – | – | – | 4 |
| 50–55 | – | – | – | – | – | – | 1 | 3 | 1 | – | 1 | – | – | 1 | 1 | 1 | – | – | – | 9 |
| 55–60 | – | 1 | 1 | – | – | 1 | – | – | 1 | – | 1 | – | 1 | – | – | 1 | – | – | – | 7 |
| 60–65 | – | – | – | 1 | – | – | 2 | – | 3 | – | 1 | 1 | 1 | – | – | – | – | – | – | 9 |
| 65–70 | – | – | – | – | – | – | – | – | 1 | – | 1 | 1 | – | – | – | – | – | – | – | 3 |
| 70–75 | – | – | – | 1 | – | – | 1 | – | – | – | – | – | – | 1 | – | – | – | – | 1 | 4 |
| 75–80 | – | – | – | – | 1 | – | 2 | 1 | – | 1 | – | 1 | 1 | 1 | – | – | – | – | – | 8 |
| 80–85 | – | – | – | – | – | – | – | 1 | – | – | 1 | – | – | – | 1 | 1 | – | – | – | 4 |
| 85–90 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 90–95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 95–100 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| 100–105 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 1 |
| Totals.... | 0 | 1 | 1 | 5 | 2 | 2 | 12 | 7 | 10 | 5 | 7 | 6 | 7 | 8 | 6 | 6 | 1 | 0 | 1 | 87 |

TABLE XVI—*Showing the Correlation between the Hatching Quality of Eggs and Winter (November to March) Egg Production. Hatching Season of 1909. Yearling Hens only.*

| Winter Egg Production. | Per Cent. of Fertile Eggs Hatched. | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | 95–100 | 100–105 | |
| 0–5 | – | – | – | – | 1 | – | – | – | 1 | – | 1 | 1 | 1 | 1 | – | – | – | – | – | – | 1 | 7 |
| 5–10 | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 2 | – | – | 1 | – | – | – | 4 |
| 10–15 | – | – | – | – | – | – | – | – | 1 | 1 | – | – | 2 | 2 | – | – | – | – | 1 | – | – | 7 |
| 15–20 | – | – | – | – | – | 1 | – | – | – | 1 | – | – | 1 | – | 1 | 1 | 1 | 1 | – | – | – | 10 |
| 20–25 | 2 | – | – | – | – | – | – | – | 1 | 1 | 1 | – | – | – | 1 | 1 | – | – | – | – | – | 5 |
| 25–30 | – | – | – | – | – | – | – | – | 1 | – | – | 1 | 1 | 1 | – | – | – | – | – | – | – | 6 |
| 30–35 | – | – | 1 | 1 | – | – | – | – | 1 | – | 4 | – | 1 | – | – | – | – | – | – | – | – | 8 |
| 35–40 | 1 | – | – | – | – | – | – | – | – | – | 1 | – | – | 1 | – | – | – | – | – | – | – | 3 |
| 40–45 | – | – | – | – | – | – | 1 | 1 | 2 | – | – | – | – | – | 1 | – | – | – | – | – | – | 5 |
| 45–50 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 1 |
| 50–55 | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| 55–60 | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| Totals. | 3 | 0 | 1 | 1 | 2 | 0 | 2 | 1 | 9 | 2 | 8 | 2 | 8 | 5 | 6 | 2 | 2 | 2 | 1 | 0 | 1 | 58 |

These coefficients (cf. p. 134) indicate that the present statistics show in general a sensible correlation between the winter egg laying and the per cent. of fertile eggs hatched during the hatching season. The correlation coefficient for 1908 is roughly 4 times its probable error, while that for 1909, all birds included, is 2.4 times its probable error. The 1909 pullets alone show a very low coefficient, which, taken by itself, could only be regarded as not significantly different from zero. It, however, is negative like all the other coefficients. There is little doubt that this 1909 pullet correlation would have been higher, had there been data from a larger number of birds. All the figures taken together indicate with a high degree of probability that there is a real and significant relationship between the phenomena shown by the statistics. The negative sign of the coefficients indicates that the relation is of the sort that *the higher the winter egg production the lower is the percentage of fertile eggs hatched and vice versa.*

Putting all the results together the present statistics show that while the high winter layer is not essentially different from the poor winter layer in regard to the fertility of eggs she is on the average distinctly inferior in respect to the hatching quality of her eggs. The hen that has laid heavily during the winter produces during the hatching season fewer viable chicks from a given number of fertile eggs.

## The Fertility and Hatching of Eggs in the Pullet and Second Year of Life.

In this section we have to do with the questions raised in paragraph 5 of the statement of problems in the introduction. The questions were: To what extent are the fertility and hatching quality of her eggs innate, unchangeable characteristics of a bird? If a pullet produces eggs shown above the average for pullets in either fertility or hatching quality, will the same bird's eggs in the second year of life be above the average for yearling hens in these respects?

To answer these questions it will be clearly necessary to appeal again to the method of correlation. Correlation tables must be formed which have, to take fertility of eggs as an illustrative case, as one variable the percentage eggs infertile in the pullet year, and as the other variable the percentage of the

TABLE XVII—*Showing the Correlation between the Pullet and Second Year Performance in Respect to Fertility of Eggs.*

| Per Cent. Infertile—Pullet Year. | Per Cent. Infertile—Second Year. | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | 95–100 | 100–100 | |
| 0– 5 | 3 | 1 | – | – | 1 | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 6 |
| 5–10 | 5 | 1 | 2 | – | – | 1 | – | – | – | 1 | – | – | – | – | – | – | – | 1 | – | – | – | 11 |
| 10–15 | 5 | 1 | 1 | – | – | – | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 | 12 |
| 15–20 | 2 | 1 | – | – | 1 | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | 6 |
| 20–25 | 5 | 3 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 8 |
| 25–30 | 1 | 1 | – | 1 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | 4 |
| 30–35 | 2 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 35–40 | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 40–45 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 45–50 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 50–55 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 55–60 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 60–65 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 65–70 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 70–75 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 75–80 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 80–85 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 85–90 | – | 1 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 |
| Totals.. | 26 | 10 | 3 | 1 | 2 | 2 | 2 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 52 |

TABLE XVIII—*Showing the Correlation between the Pullet and Second Year Performance in Respect to Hatching Quality of Eggs.*

| Per Cent. of Fertile Eggs Hatched—Pullet Year. | Per Cent. of Fertile Eggs Hatched—Second Year. | | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | 95–100 | 100–105 | |
| 0– 5 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 5–10 | 1 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | 1 |
| 10–15 | – | 1 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 2 |
| 15–20 | – | – | – | 1 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| 20–25 | – | – | – | – | – | – | – | – | 2 | – | – | 1 | – | – | – | – | – | – | – | – | – | 3 |
| 25–30 | – | – | – | – | – | – | – | 1 | 1 | – | – | – | – | – | 2 | – | – | – | – | – | – | 4 |
| 30–35 | 1 | – | – | – | – | – | 1 | – | – | – | 1 | – | – | – | – | – | – | 1 | – | – | – | 4 |
| 35–40 | 1 | – | – | – | – | – | – | – | – | – | – | 1 | – | 1 | – | – | – | – | – | – | – | 3 |
| 40–45 | – | – | – | – | – | – | – | – | – | – | – | – | 2 | – | – | – | – | – | – | – | – | 2 |
| 45–50 | – | – | – | – | – | – | – | – | – | – | – | 2 | 2 | 1 | – | 1 | – | – | – | – | – | 6 |
| 50–55 | – | – | – | – | 1 | – | – | – | – | – | – | 1 | – | 2 | – | – | – | – | – | – | 1 | 5 |
| 55–60 | 1 | – | – | – | 1 | – | 1 | – | 1 | – | 2 | – | – | – | – | – | – | – | – | – | – | 6 |
| 60–65 | – | – | – | – | 1 | – | – | – | 1 | – | – | 1 | – | – | – | – | – | – | – | – | – | 2 |
| 65–70 | – | – | – | – | 2 | – | – | – | – | 1 | – | – | – | – | 1 | – | – | – | – | – | – | 4 |
| 70–75 | – | – | – | – | – | – | – | – | 1 | – | – | 1 | – | – | – | 1 | – | – | – | – | – | 3 |
| 75–80 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 80–85 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | – | – | 1 |
| 85–90 | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | 2 |
| 90–95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | 1 |
| 95–100 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 100–105 | – | – | – | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | – | 1 |
| Totals.... | 4 | 1 | 0 | 1 | 4 | 0 | 2 | 1 | 7 | 1 | 6 | 2 | 7 | 4 | 5 | 1 | 2 | 2 | 1 | 0 | 1 | 52 |

same birds' eggs infertile in the second breeding year. We have available complete records for two successive hatching seasons of 52 birds. The correlation tables for per cent. of infertile eggs and per cent. of fertile eggs hatched for these birds are given in Tables XVII and XVIII.

From these tables the variation constants given in Table XIX have been calculated.

TABLE XIX.

*Constants for First and Second Years' Hatching Records of the Same Birds.*

| Constant. | Per cent. infertile. | Per cent. fertile eggs hatched. |
|---|---|---|
| Pullet year mean | 16.83±1.28 | 49.81±2.03 |
| " " standard deviation | 13.66±0.90 | 21.67±1.43 |
| Second year mean | 14.42±2.00 | 51.63±2.29 |
| " " standard deviation | 21.37±1.41 | 24.46±1.62 |
| Coefficient of correlation | -0.111±0.092 | 0.331±0.083 |

From these tables the following points are to be noted:

1. There is comparatively little difference in the mean fertility or mean hatching quality of the eggs of this group of birds in the two years, so far as the data enable any conclusion to be drawn. This result would seem to indicate that the supposed superiority of hens over pullets in breeding performance arises in the main from the fact that the hens kept as breeders the second year are usually selected, consciously or unconsciously with regard to their first year breeding records. An average improvement of about two per cent, such as is shown by this group of birds, is certainly not indicative of any marked tendency for a bird to be a better breeder in her second year than in her first.

2. The variability, both in regard to fertility and hatching quality of eggs is absolutely and relatively greater in the second year than in the first.

3. Having regard to the magnitude of its probable error the correlation in respect to the fertility of eggs in first and second year is probably to be regarded as not significant. In other words it would appear that, so far as may be judged by the

present statistics, on the average a bird whose eggs run high in fertility in the pullet year is as likely as not to produce eggs running low in fertility in the second year, and *vice versa*. This result is independent of the fact that the birds were with cockerels of generally equal breeding ability in the two years, as shown by their pen averages.

4. There is a significant positive correlation between the percentage of fertile eggs hatched from the same group of birds in two successive breeding years. The coefficient here (0.331) is 4 times its probable error. This result means that in the long run the bird whose fertile eggs give high percentage hatches in the pullet year, will show the same characteristics in her second breeding year. And similarly the bird whose fertile eggs hatch poorly in her pullet year will on the average, make the same kind of a record in her second year. This result emphasizes the importance of a carefully kept hatching record when one is saving pullets for the next year's breeding work or to furnish eggs to sell for hatching.

## Are the Fertility and Hatching Quality of Eggs Inherited Characters?

In this section we shall undertake the discussion of a very interesting and, at the same time difficult point. Theoretically it is a simple matter to determine whether the two characters, fertility and hatching quality of eggs, are inherited. If the question be put in this form: "Will the daughters of a hen whose eggs are above the average (for mothers) in percentage fertility produce eggs which will in turn be above the average (for daughters) in fertility?" it is at once apparent that the necessary procedure is to form a correlation table in which one variable is the percentage fertility of the mother's eggs and the other the percentage fertility of the daughters' eggs. The correlation coefficient determined from such a table should then be a measure of the degree to which this character is inherited from mother to daughter. The same line of reasoning and treatment of the data is also to be adopted to determine whether the hatching quality of eggs is inherited from mother to daughter. While the problem is thus theoretically simple, actually there are a number of difficulties as will presently appear.

TABLE XX—*Showing the Correlation between Mother and Daughter in Respect to Fertility of Eggs.*

| Daughter's Per Cent. Infertile | Mother's Per Cent. Infertile. | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | |
| 0–5 | 4 | 18 | 5 | 6 | 8 | 1 | 3 | – | – | 1 | – | 46 |
| 5–10 | – | 5 | 1 | – | 1 | – | – | – | – | – | 1 | 8 |
| 10–15 | 1 | 3 | – | 3 | – | – | – | 1 | – | – | – | 8 |
| 15–20 | 1 | 1 | 1 | – | 1 | 1 | – | – | – | – | – | 5 |
| 20–25 | – | 1 | – | 3 | – | 1 | – | – | – | – | – | 5 |
| 25–30 | 1 | 2 | – | – | – | – | – | – | – | – | – | 3 |
| 30–35 | – | 4 | 1 | – | – | – | – | – | – | – | – | 5 |
| 35–40 | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| 40–45 | 1 | – | – | – | – | – | – | – | – | – | – | 1 |
| 45–50 | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 50–55 | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 55–60 | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 60–65 | 1 | – | – | – | – | – | 1 | – | – | – | – | 2 |
| 65–70 | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 70–75 | – | 1 | – | – | – | – | – | – | – | – | – | 1 |
| 75–80 | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 80–85 | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 85–90 | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 90–95 | 1 | – | – | – | – | – | – | – | – | – | – | 1 |
| 95–100 | – | – | – | – | – | 1 | – | – | – | – | – | 1 |
| Totals. | 10 | 36 | 8 | 12 | 10 | 4 | 4 | 1 | 0 | 1 | 1 | 87 |

TABLE XXI—*Showing the Correlation between Mother and Daughter in Respect to Hatching Quality of Eggs.*

| Daughter's Per Cent. of Fertile Eggs Hatched. | Mother's Per Cent. of Fertile Eggs Hatched. | | | | | | | | | | | | | | | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | |
| 0–5 | – | 2 | – | – | 1 | – | – | – | 1 | 4 | – | – | – | – | – | 8 |
| 5–10 | – | – | – | 1 | – | – | – | – | – | 1 | – | – | – | – | 1 | 3 |
| 10–15 | – | – | – | – | – | – | – | – | – | 2 | – | – | – | – | – | 2 |
| 15–20 | – | – | – | – | – | – | – | – | 1 | 1 | – | – | – | 1 | – | 2 |
| 20–25 | – | – | – | – | – | – | – | – | 1 | 1 | – | – | – | – | – | 2 |
| 25–30 | – | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | 1 |
| 30–35 | – | – | 3 | – | – | – | 1 | – | 2 | – | – | – | – | – | – | 6 |
| 35–40 | – | – | – | – | 1 | – | – | – | 2 | – | – | 1 | – | – | – | 4 |
| 40–45 | – | 1 | 1 | – | 2 | – | – | 1 | 1 | 2 | – | – | – | – | – | 8 |
| 45–50 | – | – | – | – | 1 | – | – | – | 1 | 1 | – | – | – | 1 | – | 4 |
| 50–55 | – | – | 2 | – | 1 | – | 1 | – | – | 3 | – | 1 | 1 | – | – | 9 |
| 55–60 | – | – | 2 | – | 1 | 2 | – | 1 | 1 | – | – | – | – | – | 2 | 7 |
| 60–65 | – | 1 | 1 | 2 | – | 2 | – | – | – | 3 | – | – | – | – | – | 9 |
| 65–70 | – | – | – | 1 | – | – | 1 | – | – | 1 | – | – | – | – | – | 3 |
| 70–75 | – | – | – | – | – | – | – | 1 | 1 | – | 2 | – | – | – | – | 4 |
| 75–80 | – | – | – | 1 | – | – | – | 2 | – | 2 | 2 | – | – | – | 1 | 8 |
| 80–85 | – | – | – | – | – | 1 | 1 | – | – | 2 | – | – | – | – | – | 4 |
| 85–90 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 90–95 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | 0 |
| 95–100 | – | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | 1 |
| 100–105 | – | – | – | – | – | – | – | – | 1 | – | – | – | – | – | – | 1 |
| Totals... | 0 | 4 | 9 | 5 | 7 | 3 | 4 | 5 | 12 | 24 | 5 | 2 | 1 | 2 | 4 | 87 |

At the outstart it will be well to examine correlation tables such as have been described correlating mother and daughter with respect to fertility and to hatching quality of eggs. Such tables are given as Tables XX and XXI.

The constants calculated from these tables are given in Table XXII.

TABLE XXII.

*Constants Calculated from Tables XX and XXI.*

| Constant. | Fertility, table XX. | Hatching quality, table XXI. |
|---|---|---|
| Mothers' mean | 13.88±1.49 | 52.96±1.23 |
| " standard deviation | 20.61±1.05 | 17.00±0.87 |
| " coefficient of variation | 148.47±17.66 | 32.00±1.80 |
| Daughters' mean | 13.65±1.38 | 47.67±1.80 |
| " standard deviation | 19.10±0.98 | 24.92±1.27 |
| " coefficient of variation | 139.96±15.87 | 52.27±3.32 |
| Coefficient of correlation | —0.035±0.072 | 0.031±0.072 |

From this table we note the following points:

1. The figures apparently do not indicate that there is any correlation between mother and daughter with regard to either of the characters considered. Neither coefficient of correlation sensibly differs from zero.

2. The mothers, though a selected class are not less variable than the daughters so far as per cent. of infertility of eggs is concerned. They are much less variable than the daughters in per cent. of fertile eggs hatched. In selecting pullets for breeding in 1909 (i. e., "daughters" of the present discussion) particular attention was paid to the breeding records of their mothers as regards per cent. of fertile eggs hatched. This means that the mothers which are in the correlation tables XX and XXI are a selected group, whereas the daughters in these tables are not selected at all, with reference to their own fertility and hatching records. While some attention was paid to fertility of eggs in this selection of breeding stock, the selection was not so close as in regard to per cent. of fertile eggs hatched.

3. There is a much more marked diminution of the daughters' mean below the mothers' mean in the case of hatching

quality than in the case of fertility. This is again to be explained as the result of the closer selection with reference to the one character than to the other. The mothers' mean fertility of eggs is not significantly above the general population mean. Hence the daughters' mean shows no sensible lowering as compared with the mothers. On the other hand the mothers' mean percentage of fertile eggs hatched is well above the general population mean (52.96 as compared with 37.24) and consequently it is to be expected that there will be a relatively more pronounced reduction of the daughters' mean.

Let us now examine more particularly the result stated in paragraph 1, viz., that there is no *apparent* parental inheritance of these characters, fertility and hatching quality of eggs. It is conceivable that the observed correlation coefficients have their values reduced by the action of various circumstances affecting the statistical material, not yet taken account of. In other words there may be a real inheritance of these characters, fertility and hatching quality of eggs, and yet it may be so masked by other factors as to show no trace of itself in the statistical table. It is necessary to determine, if possible, whether this is the case.

First, let us see whether the selection of mothers may have been the factor which has reduced the parental correlation. It has been shown by Pearson * that when the selection of a parent is stringent with reference to any character, the correlation between parent and offspring will be much reduced. The formula covering the case which we have to deal with here is,

$$R_{12} = \frac{s_1}{\sigma_1} \frac{r_{12}}{\sqrt{1 - \left(1 - \frac{s_1^2}{\sigma_1^2}\right) r_{12}^2}}$$

wherein the significance of the letters is as follows, stated in terms of the present problem:

$R_{12}$ = correlation between mother and daughter *after* selection of mothers has occurred. This is the observed coefficient of correlation of Table XXII.

$s_1$ = standard deviation of mothers after selection.

$\sigma_1$ standard deviation of general population from which mothers were drawn.

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* Phil. Trans. Roy. Soc. Vol. 200 A, p. 39.

$r_{12}$ = correlation between mothers and daughters in the absence of (or preceding) any selection of mothers.

We have the following observed values for these quantities.

| Fertility of Eggs. | Hatching Quality of Eggs. |
|---|---|
| $R_{12} = -0.035$ | $R_{12} = 0.031$ |
| $s_1 = 20.61$ | $s_1 = 17.00$ |
| $\sigma_1 = 15.00$ | $\sigma_1 = 17.99$ |

It is at once apparent that in the case of fertility of eggs there was no effective selection of the mothers. The variability of the mothers is actually greater than that of general population from which they were drawn. In the case of the hatching quality of eggs the selection was far from stringent, as measured by the variabilities. We get in this case

$$r_{12} = 0.034$$

This indicates that the small observed value of the parental correlation is not to be accounted for, except in an insignificant degree, by the selection of mothers. This is the result which was to be expected since the selection was so slight.

So far we have discussed the inheritance of the characters fertility and hatching quality of eggs in the female line only, i. e., from mother to daughter. It is a pertinent question to ask whether these characters may not be transmitted through the male line. It is quite conceivable that this might be the case just as in dairy cattle milking qualities are transmitted through the male line. Unfortunately it is a very difficult matter to determine whether any character which only reaches its objective expression in the female is transmitted through the male line. The reason for this is obvious. It is not possible to get any good measure of the innate germinal constitution of a male individual with reference to any such female character. Thus a male bird may bear within its germ cells the tendency to produce good hatching quality in the eggs of its daughters and yet this fact cannot be distinguished except through the performance of the daughters themselves. These considerations make it necessary to adopt a somewhat different method of study than that which is used in the investigation of inheritance in the female line.

The only practical measurement which can be obtained regarding male birds and which is pertinent in the present connection is the average fertility and hatching quality of the eggs

TABLE XXIII.

*Comparison of Fathers' Average Pen Records of Infertility and Hatching of Eggs, with the same Characters in their Daughters.*

| Cockerel number. | Average per cent. of infertile eggs shown by females mated with the male designated. (Father's pen average infertility.) | Average per cent. of infertile eggs shown by the daughters of the designated male. | Average per cent. of fertile eggs hatched shown by female mated with designated male. (Father's pen average of hatching quality. | Average per cent. of fertile eggs hatched shown by the daughters of the designated male. |
|---|---|---|---|---|
| D 31 | 8.9 | 9.7 | 46.0 | 41.2 |
| D 32 | 16.7 | 0 | 44.3 | 61.0 |
| D 60 | 19.2 | 6.3 | 26.4 | 38.3 |
| D 17 | 20.3 | 1.0 | 41.4 | 70.0 |
| D 65 | 20.6 | 10.7 | 31.4 | 65.0 |
| D 26 | 20.8 | 78.0 | 50.3 | 76.5 |
| D 35 | 21.0 | 16.5 | 32.1 | 44.3 |
| D 11 | 22.4 | 49.6 | 33.8 | 40.5 |
| D 70 | 22.5 | 6.0 | 36.5 | 60.1 |
| D 16 | 23.0 | 1.8 | 24.6 | 54.7 |
| D 68 | 26.0 | 13.1 | 48.2 | 40.7 |
| D 5 | 26.6 | 7.7 | 26.2 | 33.0 |
| D 56 | 27.0 | 3.0 | 25.6 | 35.0 |
| D 61 | 29.0 | 25.2 | 31.4 | 38.4 |
| D 57 | 34.8 | 10.0 | 34.2 | 36.2 |

laid by all the birds in the pen headed by each cockerels. Provided sufficiently large numbers of females are used with each male in a breeding pen so that it may be supposed that they give a fair random sample of breeding females in general, the average fertility and hatching quality of eggs from the pen through the whole season may be taken as in some degree a measure of that particular male bird's breeding ability. Assuming that the females represent average samples, differences in the average fertility and hatching quality of the eggs from different pens may be attributed to innate differences in the breeding ability of the cockerels, always provided other conditions are kept the same. Now this question may be raised: What is the degree of correlation existing between a male bird's average pen fertility of eggs (such as is

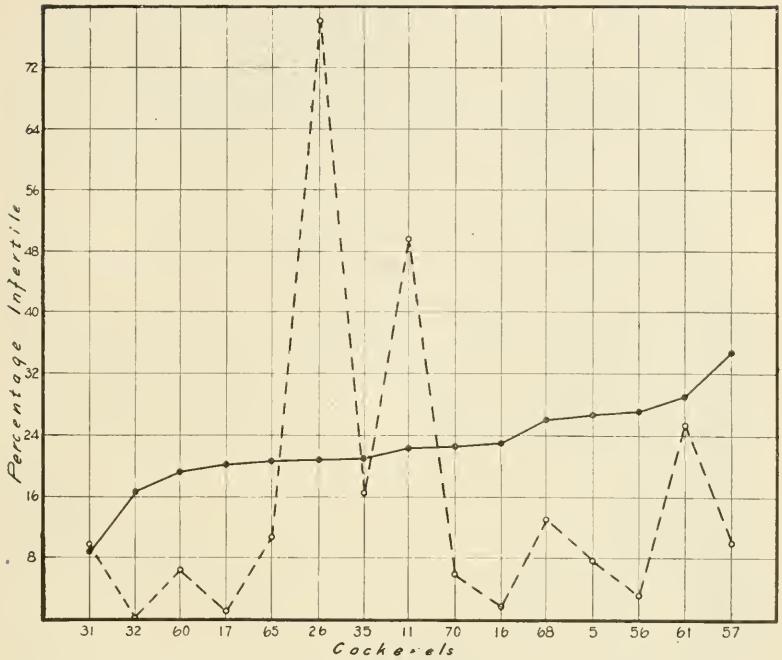


Fig. 14. Diagram showing the relation between fathers' average pen records of infertility, and the average infertility of their daughters' eggs. The solid line gives the average per cent. of infertile eggs shown by the females mated with each male. The dotted line gives the average per cent. infertile for the family of daughters corresponding to each father.

given for example in the last columns of Tables VII and VIII) and the percentage of eggs infertile and of fertile eggs hatched shown by the daughters of this male bird in the next season's breeding? To answer this question would obviously be to apply somewhat the same test to inheritance in the male line as we have to inheritance in the female line. It is impossible, however, to apply this test at present because of lack of sufficient material. The number of male birds whose daughters appear as breeders the second year is so small as to make a determination of correlation coefficients a waste of time on account of the magnitude of the probable errors which would be involved. It is possible, however, to get some little light on the matter in an indirect

way. This can be done by comparing the father's average pen fertility and average pen hatching quality of eggs as given in Table VII with the average fertility and hatching quality of eggs exhibited by his daughters. Such a comparison is made in Table XXIII and in Figures 1 and 2. The arrangement of the data in this table and the figures is fully explained in the legends.

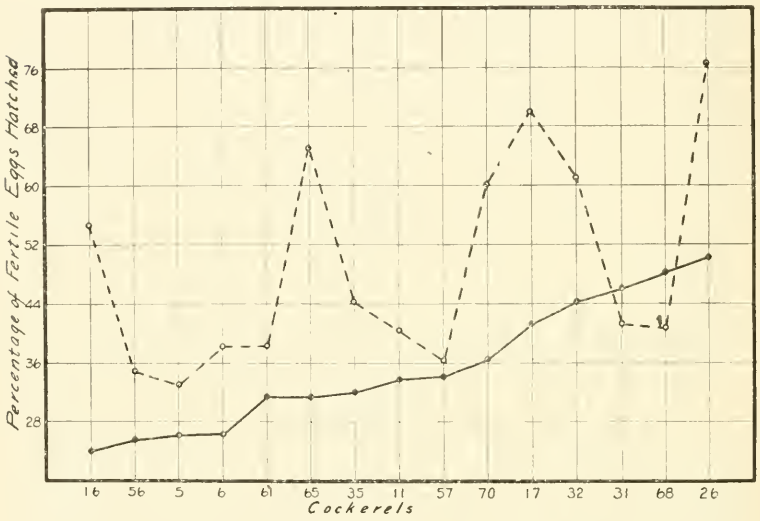


Fig. 15. Diagram showing the relation btween the fathers' average pen records of hatching quality, and the average hatching quality of their daughters' eggs. The solid line gives the average per cent. of fertile eggs hatched from the females mated with each male. The dotted line gives the average per cent. of fertile eggs hatched for the family of daughters corresponding to each father.

From the table and the diagrams we note the following points; it must be understood that, on account of the meagerness of the data, these results are simply suggestions to be tested by further work, rather than definite conclusions:

1. There clearly is no significant relationship, so far as the present data show, between the father's average pen percentage of eggs infertile and the daughters' average for the same character. The zigzag daughter line in Fig. 14 shows no tendency to parallel the line for the fathers.

2. With reference to the percentage of fertile eggs hatched the case appears to be somewhat different. Here, as is shown in Fig. 15, there is a distinct tendency for the zigzag line of daughter averages to run more or less parallel to the fathers' line. In other words, there is some indication of a distinct tendency for the daughters of a male whose average pen record for hatching quality of eggs is high to show the same characteristic themselves. Too much stress must not be laid upon the result, however, because of the small number of males included in the statistics.

3. These results, so far as they go, accord with those previously obtained in so far as that there appears to be a difference in the behavior of the character "fertility of eggs" as distinguished from "hatching quality." Fertility seems to be much more a matter of external factors than hatching quality, which appears to be very largely determined by innate constitutional characters. This point will be more fully discussed farther on.

We may now look at the question of the inheritance of these characters under discussion in still another way, namely from the standpoint of collateral inheritance. Let us turn to an examination of the so-called "fraternal" correlations respecting fertility and hatching quality of eggs. The question here is this: if one sister in a family has a percentage of fertility above the average will her other sisters (i. e., birds of the same family) tend to have fertility records above the average and *vice versa?* And similarly if one sister shows an unusually high percentage of fertile eggs hatched will the other sisters of the same family in general show hatching records above the average, and *vice versa?* It is plain that if sisters are in general alike in respect to either of these characters fertility or hatching power of eggs, it will indicate that to that extent these characters are inherited.

In order to determine whether there is on the average a closer resemblance between sisters in respect to these characters than exists between individuals taken at random it is necessary once more to appeal to the method of correlation. In forming the correlation tables in this case, however, it is necessary to adopt a slightly different method than that which was used in the case of mother and daughter records. When the correlation between mother and daughter is determined we are dealing with two entirely separate classes of individuals belonging to differ-

TABLE XXIV.

*Showing the Correlation between Sisters in Respect to Percentage of Eggs Infertile.*

| Per Cent. of Eggs Infertile | Per Cent. of Eggs Infertile. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | Totals. |
| 0–5 | 50 | 16 | 14 | 6 | 6 | 4 | 10 | 3 | — | — | — | — | — | — | 4 | 113 |
| 5–10 | 16 | 4 | — | 2 | 2 | 2 | 2 | 2 | — | — | — | — | — | — | 2 | 32 |
| 10–15 | 14 | — | 8 | — | 2 | — | — | — | — | — | — | — | — | — | — | 24 |
| 15–20 | 6 | 2 | — | — | — | — | — | — | — | — | — | — | — | — | 1 | 9 |
| 20–25 | 6 | 2 | 2 | — | — | 1 | 1 | 1 | — | — | — | — | — | — | — | 13 |
| 25–30 | 4 | 2 | — | — | 1 | — | 1 | 1 | 1 | — | — | — | — | — | — | 10 |
| 30–35 | 10 | 2 | — | — | 1 | 1 | 2 | 1 | — | — | — | — | — | — | — | 17 |
| 35–40 | 3 | 2 | — | — | 1 | 1 | 1 | — | — | — | — | — | — | — | — | 8 |
| 40–45 | — | — | — | — | — | 1 | — | — | — | — | — | — | — | — | — | 1 |
| 45–50 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0 |
| 50–55 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0 |
| 55–60 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0 |
| 60–65 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0 |
| 65–70 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0 |
| 70–75 | 4 | 2 | — | 1 | — | — | — | — | — | — | — | — | — | — | — | 7 |
| Totals.. | 113 | 32 | 24 | 9 | 13 | 10 | 17 | 8 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 234 |

TABLE XXV.

*Showing the Correlation between Sisters in Respect to Percentage of Fertile Eggs Hatched.*

| Per Cent. of Fertile Eggs Hatched | Per Cent. of Fertile Eggs Hatched. | | | | | | | | | | | | | | | | | | | | | Totals. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–15 | 15–20 | 20–25 | 25–30 | 30–35 | 35–40 | 40–45 | 45–50 | 50–55 | 55–60 | 60–65 | 65–70 | 70–75 | 75–80 | 80–85 | 85–90 | 90–95 | 95–100 | |
| 0–5 | 2 | — | 2 | 1 | 2 | — | 2 | 1 | 3 | 2 | 3 | 1 | 6 | 1 | — | 1 | 2 | — | — | 1 | 30 |
| 5–10 | 1 | 1 | — | — | — | — | — | — | — | — | 1 | 2 | — | — | — | 1 | — | — | — | — | 3 |
| 10–15 | 2 | — | — | — | 1 | — | — | 2 | 1 | 1 | — | 2 | — | — | — | — | — | — | — | — | 9 |
| 15–20 | 1 | — | — | — | — | — | 2 | 1 | 1 | — | 1 | — | — | — | — | — | — | — | — | — | 7 |
| 20–25 | 2 | — | 1 | — | — | — | 1 | 1 | 2 | 1 | — | 2 | — | — | 1 | — | — | — | — | — | 11 |
| 25–30 | — | — | — | — | — | — | — | — | — | — | 1 | — | — | — | 1 | 1 | — | — | — | — | 2 |
| 30–35 | 2 | — | — | 2 | — | — | 2 | 2 | 3 | — | 1 | 2 | — | — | — | — | — | — | 1 | — | 14 |
| 35–40 | 1 | — | — | 1 | 1 | — | 2 | 1 | 1 | 1 | 1 | 1 | — | — | 1 | — | — | — | — | — | 10 |
| 40–45 | 3 | — | 2 | 1 | 1 | — | 3 | 1 | — | 1 | 1 | 1 | 2 | — | — | — | — | 1 | — | — | 16 |
| 45–50 | 3 | 2 | 1 | 1 | 2 | — | — | 1 | 1 | — | 1 | 2 | 1 | — | 1 | — | — | — | — | — | 12 |
| 50–55 | 3 | — | 1 | — | 1 | — | 1 | 1 | 1 | 1 | — | 2 | 3 | 1 | — | — | 2 | — | — | 1 | 20 |
| 55–60 | 1 | 2 | — | 1 | — | — | 2 | 1 | 1 | — | 3 | 1 | — | — | 1 | 3 | 2 | — | — | — | 18 |
| 60–65 | 6 | — | 2 | — | 2 | — | — | — | 2 | 2 | 3 | 2 | 2 | 2 | — | 2 | 2 | — | — | 1 | 26 |
| 65–70 | 1 | — | — | — | — | — | — | — | — | 1 | — | 2 | 2 | — | — | 2 | 2 | — | — | 1 | 9 |
| 70–75 | — | — | — | — | 1 | 1 | — | 1 | — | 1 | — | 1 | — | — | — | 3 | — | — | — | — | 8 |
| 75–80 | 1 | 1 | — | — | — | 1 | — | — | — | — | 2 | 3 | 2 | 2 | 3 | — | 2 | — | — | 1 | 18 |
| 80–85 | 1 | — | — | — | — | — | — | — | — | — | 2 | 2 | 2 | — | — | 2 | 2 | — | — | — | 14 |
| 85–90 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0 |
| 90–95 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 0 |
| 95–100 | 1 | — | — | — | — | — | — | — | — | — | 1 | — | 1 | 1 | — | 1 | 2 | — | — | — | 7 |
| Totals.. | 30 | 3 | 9 | 7 | 11 | 2 | 14 | 10 | 16 | 12 | 20 | 18 | 26 | 9 | 8 | 18 | 14 | 0 | 0 | 7 | 234 |

ent generations. We may properly enter one set of individuals on one side of the correlation table, as the primary or $x$ variable and the other set on the other side of the table as the secondary or $y$ variable (cf., Table XXI). When we come to deal with pairs of sisters all of the same age, however, there is no good reason for taking one sister of a pair as the primary or $x$ variable rather than the other. Therefore, in such cases it is necessary in order to arrive at a correct result to enter each individual of a pair of sisters twice; once as the $x$ variable and once as the $y$ variable of the correlation table.* This has been done in forming the two tables XXIV and XXV which show the correlation between sisters in respect to fertility and hatching quality of eggs respectively. In forming these tables every possible pair of sisters has been entered twice, with first one and then the other as the primary variables in the manner indicated.

From these tables the following coefficients have been calculated:

Correlation between sisters in respect to per cent. of eggs infertile $r = -0.064 \pm .062$.

Correlation between sisters in respect to per cent. of fertile eggs hatched $r = 0.188 \pm .060$.

From these values we note that:

1. There is no sensible correlation between sisters in respect to the percentage infertility of eggs. A bird having a percentage of infertile eggs well below the average is as likely as not to have a sister whose percentage infertility will be above the average and *vice versa.*

2. In respect to the hatching quality of eggs (percentage of fertile eggs hatched) there is a definite and sensible correlation between sisters. *This means that, in general, sisters of birds whose eggs are above the average in hatching quality have their eggs also above the average in respect to this character.* In other words, the data would indicate that there is a sensible degree of what may be spoken of as "fraternal" or

* The necessity for dealing with material of this character is the way indicated has been dully discussed by Pearson in his memoir on homotyposis, (Phil. Trans. Roy. Soc., Vol. 197A, pp. 285-379, 1901), and by Pearl in connection with a study of homogamy in the conjugation of Paramecium (Biometrika, Vol. 5, pp. 213-297, 1907).

collateral inheritance of the character "hatching quality of eggs" even though this character is *apparently* not inherited in the ancestral line.

At first thought it would seem that there is a contradiction here in saying that there is collateral but not parental inheritance. How can sisters be more alike than a random sample of the general population except because of the fact that they are the progeny of the same parents? The contradiction is only apparent and not real, however. It has been shown by Pearson * that we may expect to get relatively high coefficients of fraternal inheritance associated with low or insignificant parental coefficients, whenever the phenomenon of *prepotency* in the ancestral line occurs. This is exactly what careful study of the individual records shows to exist in the present material. The point is that the absence of parental correlations with respect to fertility and hatching of eggs shown in Tables XX and XXI does not mean that one of these characters at least (hatching quality) is not inherited. It merely means that the existence of such parental inheritance is masked by the existence of varying degrees of prepotency with reference to this character amongst the mothers. The existence of such prepotency is perfectly apparent from (a) the study of individual records, and (b) the correlation between sisters as shown in Table XXVI, in regard to this character. In passing it may be remarked that this case well illustrates the danger of which lies in too hastily drawing conclusions from *mass* material without careful study of the individual cases. Putting all our material together it leads to the conclusion that the actual fact is that there is a definite inheritance amongst poultry of what has been called in this paper "the hatching quality of eggs." Yet the manner of this inheritance is such that the fact of its existence is entirely obscured in the ordinary parent-offspring correlation table compiled to test the question.

It may be mentioned here, though a detailed discussion of the point is reserved for a future paper, that this phenomenon of sensible fraternal correlations associated with the absence of parental correlation is exactly what is to be expected if the character studied is inherited in a manner similar to that

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* Pearson, K. On the Laws of Inheritance in Man. I. Inheritance of Physical Characters. Biometrika, Vol. II, pp 357-462, 1903.

observed in "pure lines" in plants (Johannsen) in the case of a sexually reproducing (i. e., not self-fertilizing) organism.

3. Fertility and hatching quality again are seen to behave differently. There is no evidence of any kind that the former represents an innate, constitutional character which is inheritable.

### SUMMARY OF SECTION.

Putting all the results of this section together it may be said that the data at present available indicate that the hatching quality of eggs measured by per cent. of fertile eggs hatched is an innate constitutional character which is definitely inherited in the female and probably also in the male line, though on the latter point more data are needed. On the other hand, there is no evidence that the character "fertility of eggs" is in any degree or manner inherited.

## Summary and Discussion of Results.

The data represented in this paper lead to results which may be summarily stated as follows:

1. So far as the present data indicate there is a small but still sensible correlation between the fertility and hatching quality of eggs. This means that in general or on the average the hen whose eggs run high in fertility will also tend to show a high hatching quality of eggs (per cent. of fertile eggs hatched) and *vice versa*.

2. Conditions of housing have a marked and definite influence on the mean or average fertility and hatching quality of eggs. In the experiments here discussed it was found that both fertility and hatching quality of eggs were very much better when the breeding was done in a "curtain-front" house, which furnished an abundance of fresh, pure air, than when it was done in what was formerly considered to be a highly desirable type of heated house, without curtain-front but with a supposedly adequate system of indirect ventilation.

3. The hatching quality of eggs is in general less variable in proportion to the mean of the character varying than is fertility.

4. The variability in respect to both fertility and to hatching quality is markedly influenced by environmental conditions (particularly housing conditions).

5. It is shown that the individuality of the female bird is a very important factor in the determination of the fertility of eggs. Different individual females have characteristic degrees of fertility of their eggs, independent (within limits) of the character of the male bird with which they are mated. This fact emphasizes the importance to the breeder of trapnesting through the breeding season at least.

6. The present statistics indicate that there is no correlation whatever between winter (November to March) egg production and the fertility of eggs laid during the subsequent hatching season. In other words, the eggs of the heavy winter layer are not more likely on the average to be infertile than are those of the light winter layer, other conditions being the same.

7. There is a distinct correlation between the winter (November to March) egg production and the per cent. of fertile eggs hatched during the subsequent breeding season. This correlation is of such sort as to indicate that in general the higher the winter egg production of a particular bird the lower will the percentage of that bird's fertile eggs hatched probably be and *vice versa*.

8. The present statistics do not show any *marked* superiority of hens over pullets in respect to breeding performance so far as either fertility or hatching quality of eggs are concerned. It must be understood that this is merely a statement of fact and does not constitute any recommendation for the use of either pullets or hens as breeders. That question involves more than the two factors here under discussion.

9. There is no indication that the fertility of eggs in the pullet year and in the second breeding year are in any way correlated. In other words, a bird whose eggs run high in fertility in the pullet year is as likely as not to produce eggs running low in fertility the second year, and *vice versa*, when mated with the same male or with males of essentially equal breeding ability as shown by their pen averages.

10. There is a significant positive correlation between the percentage of fertile eggs hatched in the pullet year and in the second breeding year. In other words, the bird whose eggs are of superior hatching quality in the pullet year will, on the average, show the same characteristic in her second year.

11. There is no evidence that the character "fertility of eggs" (measured by per cent. of eggs infertile) is in any degree or manner inherited.

12. The character "hatching quality of eggs" (measured by per cent. of fertile eggs hatched) is definitely inherited in the female line and probably also in the male line.

In considering these results as a whole there are certain matters of general significance which need some further consideration. In the first place, taking all the results of the paper together it is evident that fertility and hatching quality of eggs are very different characters. While there are great individual differences among different females in respect to the fertility of their eggs, even when mated to the same male, it still remains the fact that this character, as compared with hatching quality of eggs, is to a very large degree influenced by external circumstances. Thus we have seen that the same relative degree of fertility is not characteristic of the same bird in two successive seasons; nor is this character affected by winter egg production. It is not inherited.

On the other hand, the hatching quality of eggs is an innate constitutional character just as much intrinsic as any other physical character such as shape of body or length of limb. Relatively the same intensity or degree of this character is persistent in the same bird in successive breeding seasons. It is adversely affected by heavy winter egg production. It is inherited.

These facts raise the question as to what the hatching quality of eggs depends upon. We have used as a quantitative measure of this quality the percentage of fertile eggs hatched. But this measurable quantity depends on underlying innate biological factors. As to what these factors *in detail* are, data are lacking. It will, however, be of some value to attempt to list such general factors as are known to have some bearing on the case. At the start of such a list it can probably be safely said that any factor which tends to reduce or impair the general constitutional vigor of breeding birds in general tends also to reduce the hatching quality of the eggs from these birds. The relative "condition" or vigor of breeding birds may be impaired in variety of ways. For example, improper feeding may bring about this result. Houssay (1907) in his very thorough study

extending over six generations has investigated the effects resulting from feeding fowls a purely meat diet. He notes among other results an impairment of general constitutional vigor amongst his birds in the later generations, and also a greatly reduced hatching quality of the eggs.

The present study has shown that high winter egg production has, on the average, an adverse effect on the hatching quality of the eggs produced by the same birds in the subsequent hatching season. This again can probably be regarded as the result of a reduction of constitutional vigor following heavy laying. Continued heavy egg production involves great metabolic activity on the birds' part in the transformation of matter and energy and must fatigue the organism. It is not surprising that under such circumstances the developmental machines (fertilized eggs) produced are not absolutely perfect. The finding of a negative correlation between fecundity and hatching quality (= germinal viability or vigor) is of some general theoretical interest. There is considerable reason to believe that a similar condition of affairs exists in man. High fecundity and high infant mortality (and probably also prenatal mortality) are very generally associated. And are not the causes probably very similar in the two cases? In those social classes showing the greatest fecundity, there exist, speaking broadly, bad conditions of housing and nutrition all tending along with the organic fatigue incident to the high fecundity itself, to reduce the general vital condition or constitutional vigor, and with it the viability of the developing germ and growing organism.

Similarly adverse housing conditions most probably produce the bad effect which they have been shown (by Dryden, Stewart and Atwood, and others, as well as in the present paper) to have upon hatching quality by lowering the general vital condition of the fowls.

To this factor of constitutional vigor as affecting hatching quality of eggs the data of the present paper add another, viz., inheritance. Hatching quality of eggs is in some measure a "bred in the bone" character of poultry, and must be reckoned with as such. The existence of this factor manifests itself in two ways in our results: one by the persistence of relatively the same degree of hatching quality in the same bird in succes-

sive years, indicating to what an extent it is a character innate in the individual, and the other in the actual inheritance of this character. But if hatching quality is inherited it means that it is a character which can be improved by selective breeding. This we believe to be the case and in the breeding work of the Station this idea is being put into practice.*

The fact must not be lost sight of, however, that to be effective this selection cannot be of the "mass" character. It has been seen that *in the mass* there is no sensible inheritance of hatching quality from parent to offspring. The point is that some *individuals* possess the capability of transmitting good hatching quality of eggs to their progeny, or are prepotent with respect to this character. Other individuals, *which may be themselves just as good in respect to hatching quality of eggs*, totally lack the ability to transmit this quality to the progeny. Simply selecting birds indiscriminately on the basis of *their own* hatching records is as likely to get the latter kind of birds as the former, and will make no permanent improvement in the strain. But if a system of pedigree records is at hand an advance with each generation is possible because one by one those "blood lines" in which the transmitting ability or prepotency is absent can be discarded in favor of those in which it is present. In passing it may be said that these considerations apply with exactly the same force to breeding for egg production as to breeding for hatching quality. This point will be more fully discussed in a future paper.

The data presented in this paper emphasize the importance in practical breeding work of (a) the selection of breeding stock with reference to constitutional vigor or vitality, (b) the maintenance of the breeding birds in a vigorous condition by proper methods of housing and feeding, and (c) paying attention to the actual breeding ability (as shown by hatching performance) of the stock and the exercise of selective breeding to improve this character.

It is, of course, obvious that the present paper covers only a small part of the general subject of the factors which influence

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* Cf. a paper by the present writers having the title "Selection Index Numbers and their Use in Breeding" appearing in Amer. Nat. Vol. XLIII, No. 511, July 1909, pp. 385-400.

the fertility and hatching quality of eggs. There is need for much further work on the subject. In particular a careful and detailed study of the biological factors which underlie the observed *individuality* of both male and female birds with respect to these characters would be highly desirable. Such a study needs to be undertaken from several standpoints. One of the most urgent needs here is for a detailed study of the mating and general sexual behavior of the domestic fowl. Is the reason for the infertility of a particular hen's eggs some defect in the eggs themselves, or is it merely the result of a failure of the males ever to tread that particular hen? In other words, to what extent does preferential or assortative mating occur? Another question which needs study is as to what relation exists between frequency of copulation and fertility of eggs. Does the male whose copulations are very frequent produce a better average record of fertility than the one which treads the hens less often? These, and many other related questions which they suggest are all problems which deserve and will receive thorough investigation.

## Annotated Bibliography of Literature Dealing with Factors Influencing the Fertility and Hatching of Eggs.

In preparing this bibliography the extensive literature dealing with incubation and with all of the factors which, acting during incubation, influence the hatching of eggs has been omitted as falling outside the limits of the present discussion. The attempt has been made here to include only original papers of intrinsic importance (i. e., such as really contribute something to the subject). No effort has been made to include (a) general discussions of fertility and hatching which do not contribute new data or ideas, (b) textbooks and general treatises on the embryology of the chick which incidentally discuss the fertilization of the eggs (the only exception here is the latest and best of such works, viz., that by Lillie), (c) general treatises on poultry husbandry or some of its phases, (d) classical or medieval literature containing allusions to poultry. It is not to be hoped that, even in the restricted field covered, the bibliography is complete, but it is hoped that few contributions of importance have been overlooked. It is published simply in the belief that it will prove useful as a nucleus for a subsequent and more complete bibliographical resume of the subject treated.

Anon. 1894.

Egg Fertility.

Agrl. Student, Vol. I, No. 1, pp. 6 and 7.

Data on influence of duration of mating on fertility of eggs.

———. 1909.

Experiments at Llangamarch Wells.

Monthly Hints on Poultry (London, Eng.) Vol. IV, No. 35, July, 1909.

———. 1909.

Experiments at Llangamarch Wells Poultry Farm.

Monthly Hints on Poultry. Vol. IV, No. 37, Sept., 1909.

These two papers give detailed reports of some experiments carried out by A. J. Odam to determine very precisely (in hours) the duration of the period elapsing between mating and fertility. In one case a chick was produced from an egg laid 72 hours after mating.

———. 1906.
Fertility of Eggs.
Experiment Station Work, No. XXXIV (Farmers' Bulletin No. 251) pp. 18-22.
Gives an excellent brief summary of the published data on factors influencing fertility, up to the date of its appearance.

Atwood, H. 1909.
A Few Preliminary Experiments on the Effect of the Age of the Parents upon the Vigor of Chickens.
Amer. Breeders' Association. Vol. V, pp. 385-389.
Comparison of pullets' and hens' eggs with reference to fertility and hatching quality.

Barfurth, D. 1896.
Versuche über die parthenogenetische Furchung des Hühnereies. Arch. f. Entwicklungsmech. Vol. 2, pp. 303-351.
Data on persistence of fertility after removal of male. Detailed account of the results of incubating "virgin" eggs. Data on the vitality of spermatozoa.

Blount, Mary. 1907.
The Early Development of the Pigeon's Egg with Especial Reference to the Supernumerary Sperm Nuclei, the Periblast and the Germ Wall. Biol. Bulletin. Vol. XIII

———. 1909.
The Early Development of the Pigeon's Egg, with Especial Reference to Polyspermy and the Origin of the Periblast Nuclei. Jour. Morphol. Vol. XX, No. 1, pp. 264.
This and the preceding paper deal with certain phases of the morphology of the fertilization of the egg in birds.

Brittin, W. F. 1905.
A Hatching Experiment.
Rel. Poult. Jour. Vol. 12, No. 2, p. 237.
Effect of ration on hatching of eggs, particularly influence of feeding oyster shell. Obtained better results without it.

Brown, E. T. 1906.
Some Practical Observations on Fertile Eggs.
Farm Poultry, Vol. XVII, No. 2, p. 29.
General discussion.

Buffon. 1772.
Histoire naturelle des oiseaux.
Paris. Vol. III.
"Le coq," pp. 88-186. Pl. II. Has much interesting discussion regarding fertility, fecundity and incubation. Many references to medieval and classical literature regarding poultry.

Curtice, C. 1903.
Poultry Experiments.
R. I. Expt. Rept. for 1902. pp. 333-373.
Data on fertility and hatching of eggs in different seasons of year. No very definite conclusions.

Dryden, J. 1897.
Poultry Experiments.
Utah Agric. Expt. Stat. Bulletin 51, pp. 1-33.
Gives some data regarding the influence of the following factors on "fertility:" (a) season, (b) age of breeding stock (females), (c) exercise, (d) length of time eggs have been kept. No statement as to whether embryoes dying early were distinguished from truly infertile eggs. Results not conclusive.

————. 1907.
Poultry Experiments.
Utah Agric. Expt. Stat. Bulletin 102, pp. 203-237.
Gives data on the effect of housing on the fertility of eggs.

Féré, Ch. 1901.
Réponses à quelques questions du questionnaire concernant les oeufs et l'incubation chez les oiseaux domestiques.
Ornis, Vol. 11, pp. 425-426.

Gilbert,, A. G. 1901.
Report of the Poultry Manager.
Canada Expt. Farms Rept. 1900, pp. 251-277.
Conclusion is reached, but not supported by numerical data, that winter laying and confinement adversely affect the hatching quality of eggs.

———. 1904.
Report of the Poultry Manager.
Canada Expt. Farms Rept. 1903, pp. 239-255.
Some data on effect of housing conditions on fertility and hatching quality of eggs.

———. 1905.
Report of the Poultry Manager.
Canada Expt. Farm Rept. 1904, pp. 283-311.
Data on duration of fertility after removal of male. Maximum observed 11 days.

———. 1906.
Report of the Poultry Manager.
Canada Expt. Farms Rept. 1905, pp. 233-261.
Confirms earlier work.

Gove, Hartley. 1907.
Explain the Fertility.
Farm Poultry. Vol. 18, No. 8, p. 212.
Records of very exceptional fertility of a small flock (12 pullets).

Gowell, G. M. 1902.
Poultry Experiments in 1900-1901.
Me. Expt. Stat. Bulletin No. 79, pp. 9-40.
Data regarding influence on hatching quality of eggs of (a) method of keeping pending incubation, (b) shape and size of eggs. Also some data on relation of duration of mating to fertility of eggs. Number of eggs involved in the experiments not large.

———.
Poultry Experiments in 1902.
Me. Expt. Stat. Bulletin No. 93, pp. 69-92.
Data on variation in fertility of eggs, influence of hen, and of egg production on fertility of eggs.

———.
Poultry Experiments.
Me. Agr. Expt. Stat. Bulletin No. 130, pp. 101-132.
Data on the influence on fertility and hatching quality of (a) duration of mating, (b) previous egg production.

Graham, W. R. 1908.
Hatching and Rearing Chickens.
Ont. Dept. Agr. Bulletin 163, pp. 1-28.
Contains mass of detailed statistics regarding fertility and hatching.

Harper, E. H. 1904.
The Fertilization and Early Development of the Pigeon's Egg.
Amer. Jour. Anat. Vol. III.
Detailed description of the actual process of fertilization (union of sperm with ovum) in the pigeon.

Harvey, W. 1737.
Exercitationes de generatione animalium.
Lugduni Batavorum.
Duration of fertility after mating. States that 20th egg after a copulation developed. (Cited after Barfurth.)

Holmgren, F. 1872.
Om Kôttâtande dufvor.
Aftryck ur Upsala Lakâre-fôrenings Förhandlingar. Upsala.
In experiments with pigeons a bad effect of meat feeding on the hatching quality of eggs is noted. (Cited from Houssay.)

Houssay, F. 1907.
Variations expérimentales. Etudes sur six générations de poules carnivores.
Arch zool. expér. et gén. IV e Ser., T. VI, pp. 137-332.
This important study contains a chapter regarding the effect of a purely carnivorous diet on the fertility and hatching quality of hens' eggs.

Jarvis, L. G. 1898.
Report of Manager of Poultry Department.
Ont. Agr. Col. & Expt. Farm Rept. 1898, pp. 193-196.
Influence of duration of mating on fertility of eggs.

Kionka, H. 1894.
Die Furchung des Hühnereies.
Anat. Hefte. Vol. X. p. 393 ff.
Data on persistence of fertility after removal of male.

Kirchstein, A., und Sweers, P. 1909.
Zweite Bericht über die vergleichenden Kückenaufzuchts-Versuche.
Deutsche landw. Gefl. Ztg. Vol. 12, No. 43, p. 750.
Data regarding fertility and hatching of eggs of different breeds under the same conditions of management.

Kirchstein, A., Sweers, P., Brinkmann, E. 1909.
Dritte Bericht über die vergleichenden Kückenaufzuchts-Versuche.
Deutsche landw. Gefl. Ztg. Vol. 12, 44, p. 763.
Continuation of preceding report.

Lau, H. 1894.
Die parthenogenetische Furchung des Hühnereies.
Inaug. Dissert. Jurjew-Dorpat. p. 50.
Data on persistence of fertility after removal of male, and on vitality of spermatozoa.

Lécaillon, A. 1908.
Sur les modifications qui peuvent se produire dans la structure de la cicatricule de l'oeuf non fécondé des oiseaux.
Compt. rend. Soc. Biol. Vol. 64, No. 14, pp. 647-649.
Sur les changements qui se produisent, après la ponte, dans l'aspect exterieur de la cicatricule, de l'oeuf non fécondé de la poule.
Compt. rend. Soc. Biol. Vol. 64, No. 21, pp. 1034-1036.

Lillie, F. R. 1908.
The Development of the Chick.
New York (Holt) pp. xi. and 472.
Contains general account of the process of fertilization of the bird's egg, with reference to the existing biological literature on the subject.

Mairs, T. I. 1908.
Some Poultry Experiments.
Penn. Agr. Expt. Stat. Bulletin No. 87, pp. 1-48.
Gives statistics of fertility, hatching and weight of eggs for different breeds and months of the season.

Meyer. 1909.
Verpackung der Bruteier in Kartons oder Körben.
Deutsche landw. Gefl. Ztg. Vol. 12, No. 44, p. 764.
Data on hatching of eggs kept in different ways pending incubation.

Nottage, H. P. 1904.
Dry Feeding and Fertility.
Farm Poultry. Vol. 15, p. 204.
Percentage records for different years keeping hens and pullets separatd.

Rablaud, E. 1899.
De l'influence de la congelation sur le deéveloppement de l'oeuf de poule.
C. R. Ac. Sci. Paris, Vol. 128, p. 1183.
Effect of very low temperature prior to incubation on the development of the hen's egg.

Robinson, J. H. 1903.
Confinement and Fertility.
Farm Poultry. Vol. 14, No. 10, pp. 244 and 245.
General discussion of topic suggested in title. Gives some pertinent data obtained from close observation of a few individual birds.

———.
Still Studying Fertility.
Farm Poultry. Vol. XVII, No. 18, p. 395.
Recounts some experiments relative to influence of sexual maturity of male on fertility.

Saint-Loup, Remy. 1901.
Quelques réponses au questionnaire concernant les oeufs et l'incubation chez les oiseaux domestiques.
Ornis, Vol. 11, pp. 421-423.

Silberstein, A. J. 1898.
Facts vs. Theory.
Poultry Monthly, Sept. 1898. Copied in Rel. Poult. Jour. Sept. 1909, Vol. XVI, p. 787 and 788.
Some detailed data (from unofficial source) showing relation in a few individual instances between winter egg production and hatching of eggs.

Stewart, J. H. and Atwood, H. 1900.
Poultry Experiments.
West Virginia Expt. Stat. Bulletin No. 71, pp. 385-402.
Data on the influence of free range on the hatching of eggs.

———.

Poultry Experiments.

W. Va. Agr. Expt. Stat. Bulletin 88, pp. 147-162.

Contains detailed data on the influence of (a) mash as compared with whole grain, (b) heavy feeding as compared with light feeding, and (c) animal foods on the fertility and hatching quality of eggs.

(Symposium). 1902.

Age and Fertility.

Farm Poultry. Vol. 13, pp. 194, 215 and 240.

Subtitle—"Are well matured cockerels more desirable than vigorous cock birds."

Wellcome, F. O. 1902.

Heavy Laying and Fertility.

Farm Poultry, Vol. 13, No. 17, p. 352.

Rather general discussion. No definite figures but studied the fertility of individual birds.

Pearl, R.& Surface, F.M. Date
& hatching of eggs 1909

8vo pamphlet